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THE

AMERICAN VIGNOLA

PART II

ARCHES AND VAULTS
ROOFS AND DOMES
DOORS AND WINDOWS
WALLS AND CEILINGS
STEPS AND STAIRCASES

By WILLIAM R. WARE

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PREFACE

THE First Part of this work, which was published three years ago, treated of the Five Roman Orders, and presented a simple method of drawing them, in accordance with the proportions determined by Vignola. Chapters were added on the Intercolumniation and Superposition of Columns, and on Parapets, Balustrades, String-Courses, Pediments, and Attics.

In the Preface I said that the employment of these Elements in the composition of Doors and Windows, Wall Surfaces, Staircases, Towers and Spires, Arches and Arcades, Vaults and Domes, might some day be made the subject of a separate treatise which would be the natural sequel of the first. The present publication fulfils this promise, except that Towers and Spires are not among the topics taken up. It contains also, under the heading of Wall Treatment, a discussion of Coupled Pilasters, and of the treatment of Pilasters and of Cornices on external and internal angles, which might perhaps just as well have been put into the other volume.

Of the Nineteen Plates placed at the end of the book, three are taken from Sir William Chambers' *Civil Architecture*, though the figuring of the orders is simplified, in accordance with the system set forth in Part I. One Plate is taken from Gruner's *Fresco Painting in Italy*, one from the Comte de Clarac's *Louvre and Tuileries*, and one from Letarouilly's *Edifices de Rome Moderne*. Of the hundred and three illustrations inserted in the Text, half a dozen, and an equal number of the figures in some of the Plates, have been copied or traced from various works of reference. The remainder of the Plates and Figures have been drawn out from sketches made under my direction. For the sympathetic care and skill with which this work has been done I am much indebted to the young men who have divided the work among them, and am under special obligations to Mr. G. L. Smith, Mr. H. V. Skene, Mr. F. M. Riley, and Mr. Joseph Wilson, for serviceable criticisms and suggestions.

Milton, Massachusetts, October 1, 1905. WILLIAM R. WARE

This Second Edition contains a few slight corrections and additions.
April 1, 1913. W. R. W.

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THE AMERICAN VIGNOLA

PART II

THE First Part of this work treated of the Five Orders of classical Roman Architecture, of the Greek Orders, and of Pilasters, Pediments, Pedestals, and Attics, of the Intercolumniation and Superposition of Columns, and of Moldings and String-Courses. The present volume treats of Arches and Arcades, Vaults and Domes, Doors and Windows, Walls and Ceilings, and of Staircases, including the use of the Orders in these various features.

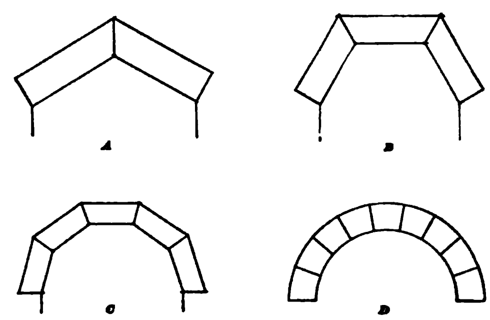


FIG. 1

ARCHES

As was said in Part I, an opening in a wall may be spanned by a single beam of wood, stone, or iron, bearing vertically on the points of support. It carries the weight of the beam itself and of whatever rests upon it. This beam is called an *Architrave*, or, sometimes, if it rests upon columns, an *Epistyle*. If the opening is spanned by two or more such beams, leaning against and mutually supporting each other, the structure is called an *Arch* (Fig. 1, *A*, *B*, *C*, and *D*). An arch not only throws its own weight and that of the load it carries upon the piers or columns that support it, but it also exerts upon them a horizontal thrust, which tends to push them apart and overthrow them. This thrust has to be met either by a horizontal tie of wood, stone, or iron, or by a sufficiently strong pier, or wall, to serve as an abutment, or buttress (Figs. 2 and 3).

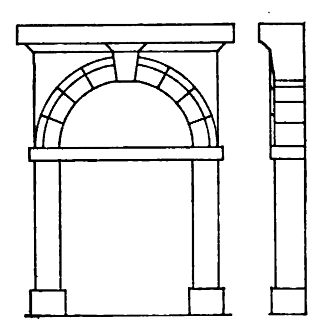


FIG. 2

The separate stones of which an arch is composed are called its *Voussoirs*. The joints that separate them are at right angles to the inner curve of the arch, which is called the *Intrados*. The outer curve, or back of the arch, is called its *Extrados* (Fig. 3 *A*).

The joints between the voussoirs and the curved joint at the extrados are not generally recognized as architectural features, any more than are the joints between the other stones of which a wall is built up. When they are so recognized, and the shape of the stones or of the voussoirs is made conspicuous, the masonry is said to be *Rusticated* (Fig. 50). Rustication and Rusticated Arches are treated on page **20**.

But the line of the extrados, like other lines that it may be considered desirable to emphasize, is generally marked by a raised molding, similar to the Tænia or Cymatium that

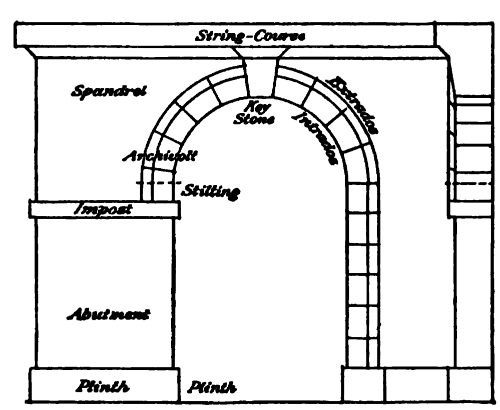


FIG. 3 (*A*)

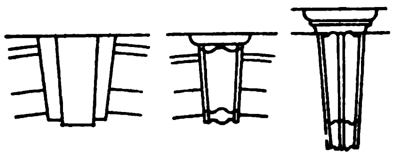


FIG. 3 (*B*)

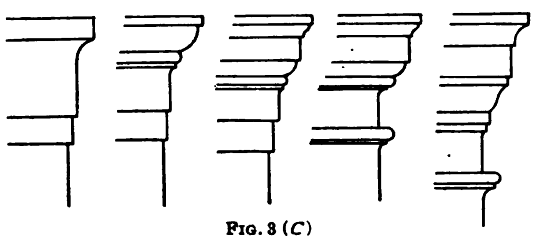


FIG. 3 (*C*)

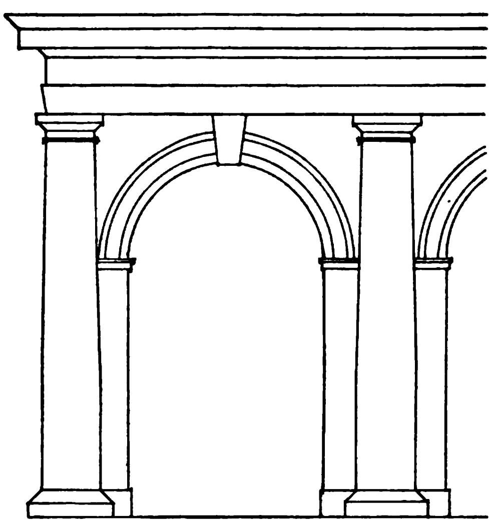


FIG. 4 (*A*)

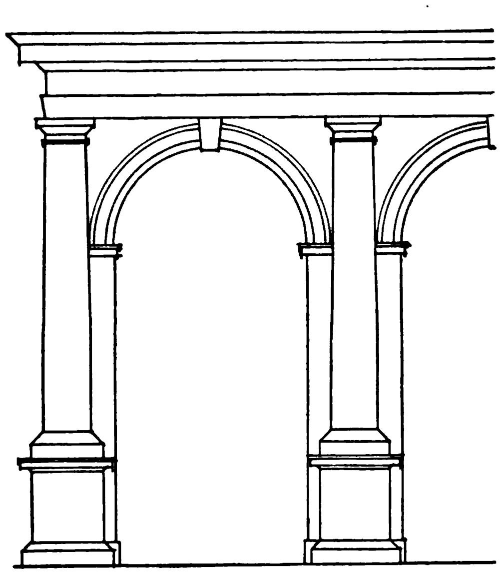


FIG. 4 (*B*)

marks the upper line of the Architrave. The face of the arch and the molding that thus circumscribes it are called the *Archivolt*. It is often composed, in imitation of the Architrave, of several bands, or fascias, with or without small moldings, or cymatia, between them (Figs. 3 and 4).

When the face of the wall that an arch supports is marked, just above the arch, by a horizontal member, or *String-Course* (Fig. 3 *A*), the upper voussoir of the arch is generally extended so as to reach and apparently support it, and it is often made to project beyond the others both in front and below, and is frequently fashioned into the shape of a corbel, console, bracket, or modillion. When thus emphasized, it is called a *Keystone*. Keystones should be higher than they are wide. They are sometimes triple. Fig. 3 *B* shows those adopted by Vignola for Doric and Corinthian arches. He omits keystones in the Tuscan and Doric arches, but in this his example has not been generally followed.

Such a string-course is sometimes, especially at the top of a wall, treated like an architrave and surmounted by a Frieze and Cornice (Fig. 4). The horizontal joint at the top of the pier, at the spring of the arch, is also generally marked by a molding, which is called an *Impost;* and at the foot of the pier is a plinth, with or without base moldings. The pier thus treated closely resembles a Tuscan or Doric pilaster, with its capital and base, or a tall pedestal; and, as in pedestal caps, a cyma recta is often used in the bed mold instead of an ovolo. Fig. 3 *C* shows forms of imposts adopted by Vignola and Palladio. In very large arches a full entablature without a frieze is sometimes used as an Impost. The top of the Impost comes naturally at the level of the center of the arch, but it is often set a little lower, so that the full semicircle may be seen above it. In this case, the arch is said to be *Stilted* (Fig. 3 *A*).

The fragment of triangular or trapezoidal wall at the side of the arch and above the Impost is called the *Spandrel*.

When the Impost is omitted, the moldings of the archivolt are continued down the pier (Fig. 3 *A*).

When a full entablature occurs just above an arch, resting upon its keystone, the face of the pier is often decorated with a pilaster, with or without a pedestal, which runs up as high as the top of the keystone and, like it, seems to support the architrave. In this case, the entablature and the pilaster may have the form and proportions of some one of the five regular Roman Orders. This combination of a full order with a wall pierced by an arch is called the Roman Arch, and sometimes the Roman Order (Fig. 4 *A* and *B*). The Greek Orders are not used with arches.

An arch may be made wider, without changing its height, by lowering the Impost, as in Fig. 5 *A*, and may be made higher, without changing its width, by lengthening the piers, as in Fig. 5 *B*. There is, in general, nothing to determine the shape of an archway, that is to say, to fix the proportion

between the width of an opening and its height, or the shape of the piers that support it, except considerations of good looks, strength, and convenience. But such a change of proportions naturally takes place in the Roman Orders merely by the change in the length of the pilasters, from seven diameters in the Tuscan to ten in the Corinthian and Composite. The piers, reckoning their height up to the architraves, then vary in shape from about two diameters by eight to two diameters by thirteen, that is, from four times their height to about seven times. If the width of the arches were kept the same, the shape of the opening would change in like manner, from the proportion of about four diameters by eight to four diameters by thirteen, or from two squares to three or four. But it is customary, in the more slender arches, to diminish this attenuation by widening the opening, thus lengthening the radius of the arch and lowering the impost (Fig. 5 *A*).

In antiquity, the openings in the Triumphal Arches vary in the ratio of width to height from about six to seven, or nearly square, in the arch at Rimini, to nearly one to three, in the arch at Ancona, the shape of the opening in each case following the general shape of the entire structure.

Elliptical Arches.—When elliptical arches are employed in place of semicircular ones, harmony of shape requires that the archways and piers, as well as the arch itself, shall be comparatively broad and low. The greater thrust of an elliptical arch also requires a wider pier (Fig. 6 *A*).

Segmental Arches.—The same considerations apply to Segmental Arches. Segmental Arches need to be stilted, to prevent an awkward meeting of the archivolt and the impost (Fig. 6 *B*).

Palladio's Motive.—In the arcades with which he surrounded the old Basilica at Vincenza, Andrea Palladio introduced a scheme that has since been known by his name (Fig. 7). The archivolt is supported by a small column that carries, for an impost, an entablature of two members, that is, an architrave and cornice, without any frieze. The other end of this architrave rests upon a pilaster, set some distance away and set edgewise, facing the small columns. This is backed by a large pilaster that runs as high as the top of the keystone of the arch and helps carry a large entablature. The space on each side, bounded by the arch and the pilaster and by the small entablature below and the large one above, is filled by a trapezoidal spandrel.

Roman Arches Without Pedestals.—Plate I.—But in the Roman Arch, in which the piers are decorated with a pilaster or column, it is customary to make the archway about twice as high as it is wide, or "two squares," and the pier about half this width, or, in the Tuscan Order, a little more. If there is no pedestal, the pilaster is made half as wide as the pier, and its height is made the same as that of the archway. The face of the pier on each side of the pilaster is thus half a

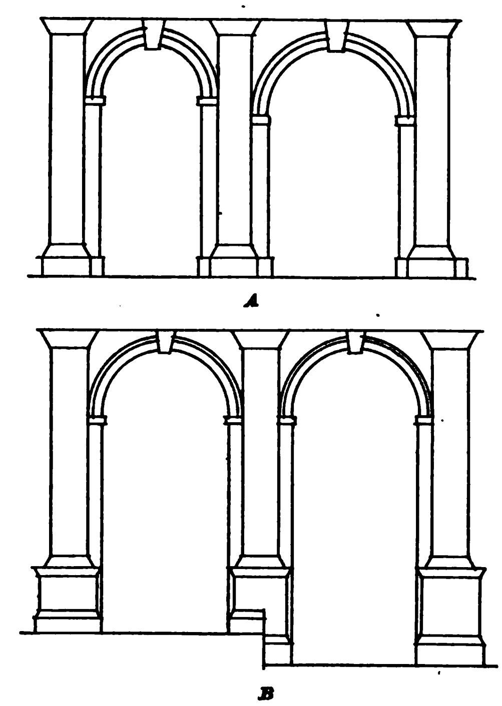


Fig. 5

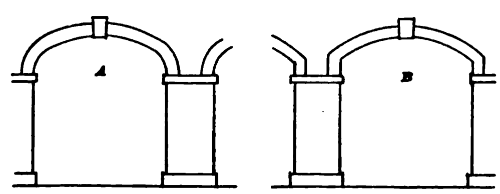


Fig. 6

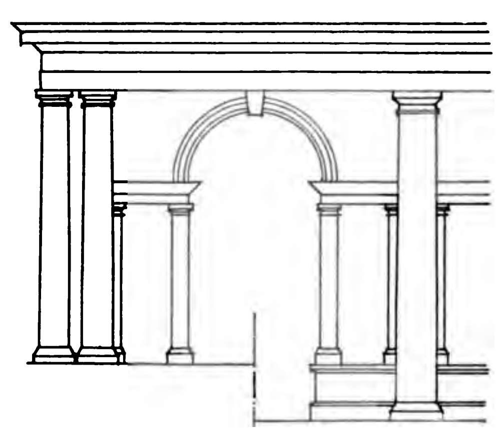


Fig. 7

diameter wide. Beneath the pilaster is set a block, or extra plinth, three-quarters of a diameter high (or a whole diameter), and there is accordingly an equal space of three-quarters of a diameter (or an entire diameter) between the top of the opening and the entablature above it. The archivolt is half a diameter wide. There is thus a space of either a quarter of a diameter or half a diameter between the extrados of the arch and the architrave above it, and the keystone is made longer than the other voussoirs by this amount.

It follows that the pier, up to the top of the impost, is about one-third as wide as the opening, which makes it about three squares high. The rectangular part of the opening, between the piers, is two-thirds as wide as it is high. These proportions obtain with exactness for the Ionic Order. In the Tuscan and Doric the opening of the archway is made a little wider, and in the Corinthian and Composite it is a little narrower, so as to be in harmony with their general character of greater heaviness or lightness (Plate I).

But here, as in the spacing of columns, and indeed as in the proportions of the Orders themselves, usage greatly varies, and precedents differ.

The proportions of the Doric Arch, however, are closely determined by the necessity of having a triglyph over each pilaster. Since the triglyphs are spaced one and one-fourth diameters on centers, the distance from axis to axis of the piers must be a multiple of one and one-fourth diameters. The best dimension is six and one-fourth diameters. This gives four triglyphs over the arch, besides the two over the pilasters, or six in all. The arches are four and one-fourth diameters in breadth by eight diameters high, or a little less than two squares. The Tuscan Arch (Plate I, *A*), which is seven diameters high, is made still wider in proportion, measuring three and three-fourths diameters.

As it is desirable to have a dentil come over each pilaster, and it is necessary that a modillion should, the distance of the Ionic pilasters on centers, must be a multiple of one-sixth of a diameter, and of the Corinthian, a multiple of two-thirds of a diameter. The opening of the Ionic Arch (Plate I, *C*) is generally made four and one-half diameters, or just half its height. This sets the pilasters six and one-half diameters on centers, or thirty-nine sixths of a diameter, which gives thirty-eight dentils over the arch, besides the two over the pilasters and three more outside at each end, making forty-six in all.

The Corinthian Arch (Plate I, *D*) is made a little more than two squares high, the height being ten diameters and the width only four and two-thirds diameters, the pilasters being six and two-thirds diameters on centers, or forty sixths of a diameter. This gives one more dentil than for the Ionic Arch and nine modillions over the arch, besides the two over the pilasters and one more at each end, or thirteen in all.

If Vignola's Composite is used, with dentils one-fourth of a diameter on centers, the opening had better be four and one-half diameters in width (or four and three-fourths), giving room for twenty-five (or twenty-six) dentils over the arch besides six others, making thirty-one (or thirty-two) in all. In Palladio's Composite Order, in which the distance apart of the blocks on centers varies considerably in different examples, the distance apart of the axes of the pilasters should be some multiple of that distance.

The proportions of the four arches shown in Plate I are those adopted by Sir William Chambers. They follow closely those published by Vignola, and conform to the figures just given. In all four, the height of the opening is just the height of the pilaster. The pilaster stands upon a plinth three-fourths of a diameter in height, and the width of the pier is two diameters, showing a half diameter on each side of the pilaster, just enough to receive the archivolt, which is, in every case, a half diameter in width.

Roman Arches With Pedestals.—Plate II.—When the pilaster stands upon a pedestal, instead of upon an extra plinth, the size and shape of the archway and of the piers are substantially unchanged. But since the pedestal takes up about a quarter of the height, being regularly one-third the height of the column, the scale of the whole order is one-fourth smaller. The diameter of the shaft, and the height of the pilaster and of the entablature, are only about three-fourths as great as when there is no pedestal. The pilaster being thus narrowed, the plain face of the pier, left on each side of it, is somewhat wider, measuring five-eighths of the new diameter instead of one-half of the old one. In the Tuscan order (Plate II, *A*), the pier is more than half the width of the opening, but in the others it is less. For though, relatively to the pilaster, the pier is one-third longer, it is only one-eighth wider. The piers with pedestals are thus of more slender proportions than those without pedestals.

Here, again, the proportions of the Doric Arch (Plate II, *B*) are predetermined, since the distance of the pilasters, on centers, must be a multiple of one and one-fourth diameters, so as to bring a triglyph over each pilaster. The only convenient arrangement is to have five triglyphs over the arch, which, with two over the

pilasters, makes seven in all. This brings a triglyph in the middle, over the keystone. The distance apart of the pilasters, on centers, is just seven and one-half diameters, and if, as usual, the pier is two and one-fourth diameters in width, the opening of the arch is five and one-fourth diameters wide by ten and two-thirds diameters high, or a little more than two squares. But Sir William Chambers, as appears in the Plate, makes the pedestal two and one-fourth diameters high instead of two and two-thirds, diminishing the height by three-twelfths of a diameter. This makes the height of the opening exactly nine and one-half diameters.

In like manner, he reduces the Tuscan pedestal from two and one-third diameters to two diameters; the Ionic, from three diameters to two and one-half diameters; and the Corinthian, from three and one-third diameters to three diameters.

Here, again, the width of the opening must be such that the Ionic and Corinthian pilasters shall come exactly under a dentil or modillion; that is, the distance of the Ionic pilasters, on centers, must be a multiple of one-sixth of a diameter, and that of the Corinthian pilasters a multiple of four-sixths of a diameter. The Ionic pilasters (Plate II, *C*) are accordingly set eight diameters on centers, or forty-eight sixths of a diameter. This gives forty-seven dentils over the arch, which, with the one over each pilaster and three at each end, makes fifty-five in all. The Corinthian pilasters (Plate II, *D*) are set eight and two-thirds diameters on centers, or fifty-two sixths of a diameter, which gives four more dentils than to the Ionic, and twelve modillions over the arch, making sixteen modillions altogether.

When there is no pedestal, the height of the opening is fixed, being the same as the height of the pilaster, and the only way of changing the shape of the opening is to change the width—either increasing it by lowering the impost and so lengthening the radius of the arch, or diminishing it by raising the impost and adopting a smaller radius—as has been said, and as is illustrated in Fig. 5 *A*. But when there is a pedestal, the shape of the opening may be changed without altering the width, by simply changing the height of the pedestal, as in the plate. This is exemplified in the Arch at Ancona, and by the lofty entrance erected by Lombardi in front of the church of Sta. Francesca Romana, near the Roman Forum.

Superposition of Arches.—Plate III.—When Roman arches are superposed, they follow the same rule that governs the superposition of colonnades. The lower diameter of the upper column or pilaster is equal to the upper diameter of the lower one. If the Diminution is, as usual, one-sixth of a diameter, it follows that the scale of the upper order is five-sixths that of the lower one. As the upper pilasters are set exactly over the lower ones, their distance on centers, as expressed in terms of the upper diameter, is six-fifths of the same distance expressed in terms of the lower diameter.

Plate III shows three examples of superposed Roman arches and one example of superposed Palladian Motives, according to Sir William Chambers. In each case, the upper order has a pedestal. Each order is figured in terms of the diameter of its own column. As in Plate II, the height of the pedestals is less than one-third the height of the columns they carry.

Here, as in the case of single arches, the pilasters must be set at such a distance on centers as shall bring a triglyph or a modillion exactly upon the axis of the pier. At *A* and *B* the pilasters of the lower order are set six and one-fourth diameters on centers, and those of the upper order seven and one-half diameters. Six and one-fourth ($\frac{25}{4}$) is five-sixths of seven and one-half ($\frac{30}{4}$), so that seven and one-half times the smaller diameter equals six and one-fourth times the larger one.

This works perfectly well where the Doric order is superposed upon the Tuscan (as at *A*), and the Ionic upon the Doric (as at *B*). But where the Corinthian arch is placed over the Ionic (as at *C*), the Corinthian pilasters must be eight diameters on centers instead of seven and one-half diameters, since eight is a multiple of two-thirds, the distance on centers of the modillions, while seven and one-half is not. The Ionic pilasters below are then six and two-thirds diameters on centers, instead of six and one-fourth, six and two-thirds ($\frac{20}{3}$) being five-sixths of eight ($\frac{24}{3}$). This gives room for thirty-nine dentils over the Ionic arch which is beneath the Corinthian one, or forty-seven in all ($6\times6\frac{2}{3}+1+6=47$); and room also for forty-four, or fifty-two altogether, over the Ionic arch which is above the Doric one ($6\times7\frac{1}{2}+1+6=52$). In the plate the dentil-bands are not divided into dentils. The Corinthian arch has fifteen modillions, instead of sixteen as in Plate II.

The lower arches are all less than two squares high, the Tuscan and Ionic openings being a little wider than when arches without pedestals are used alone. If the pedestals of the upper orders are made one-third as high as the pilasters they support, the upper arches are all more than two squares high. But these pedestals are commonly, as in the Plate, only one-fourth or one-fifth the height of the column. This makes

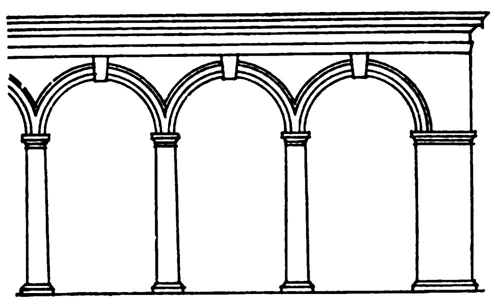


FIG. 8

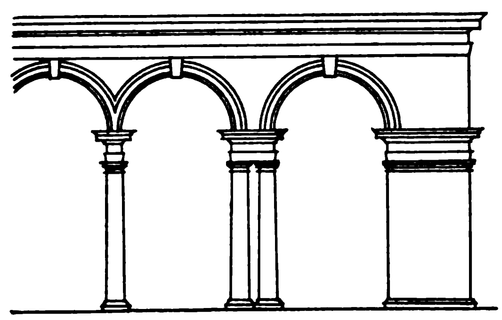


FIG. 9

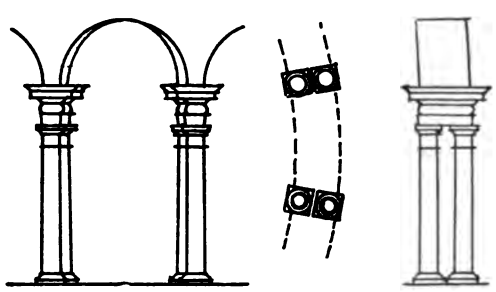


FIG. 10

the Corinthian arch exactly two squares high, and the Ionic one very nearly so.

If a Corinthian arch is set above a Doric arch, which seldom happens, either the modillions must be set nearer together or the triglyphs set farther apart, or both.

When an Ionic Palladian Motive is set over a Doric one, as in Plate III, *D*, there are seven triglyphs in the Doric entablature, and the Doric pilasters are set seven and a half diameters on centers, just as in the arch with pedestals. The Ionic pilasters are nine diameters on centers, nine ($\frac{18}{2}$) being six-fifths of seven and a half ($\frac{15}{2}$), and there is room for sixty-one dentils ($9 \times 6 + 1 + 6 = 61$).

Arcades.—A series of arches resting upon piers is called an *Arcade.* The arches sometimes come down upon a single column, instead of upon piers (Fig. 8). One of the earliest examples of this treatment is an arcade in the Palace of Diocletian at Spalato in Dalmatia, built about the year 325 A. D. But in medieval and modern times it is common. The intrados comes in line with the upper diameter of the column, and if the width of the archivolt is more than five-twelfths of the lower diameter, the two cymatia intersect one another (Fig. 9).

Sometimes the place of the pier is taken by coupled columns, which in this case generally carry a fragment of architrave, or even of a full entablature, which serves as a sort of impost to receive the archivolts, very much as in Palladio's Motive (Fig. 9). This is often used with single columns.

Sometimes, as in the Baptistry of Sta. Constanza, in Rome, and at St. Sulpice, in Paris, the coupled columns are set across the wall (Fig. 10).

But a column, or even two columns, is an insufficient abutment, and an arcade must end in a pier, if it terminates at an external angle or corner, as in Figs. 8 and 9.

At the internal angle of a courtyard or cloister, also, something firmer than a single column is needed, such as a pier, either square or L-shaped, or at least a group of three columns (Fig. 72).

VAULTS

An arch spans an opening in a wall, serving the purpose of a beam, and is no thicker than the wall itself. It carries not only its own weight, but the weight of the portion of wall above it, and has the adjacent portions of the wall as natural abutments. A *Vault* is a sort of deep arch. But it differs from an arch in that it is not used to effect passage through a wall, but answers the purpose of a floor to cover a space. It has little more than its own weight to carry, but it has no natural abutments, and tends to push over the walls that support it.

The simplest form of vault is the *Barrel*, or *Cylindrical, vault*, as shown in *A*, Fig. 11. This, like the arch, may be semicircular, elliptical, or segmental. Either kind may be reenforced or strengthened by transverse arches, of somewhat smaller radius, erected from point to point within them, which, being better buttressed, add firmness to the construction (Fig. 11 *B* and Fig. 12).

Barrel Vaults, and the Groined and Cloistered Vaults which are composed of them, are commonly built up in horizontal courses, the horizontal joints being the continuous ones (Fig. 13). But in Egyptian and Assyrian vaulting, and in the Byzantine vaulting which is derived from it, the vertical joints are the continuous ones, so that the vault consists of a succession of narrow arches, set side by side (Figs. 14 and 15).

Intersecting Cylinders.—Plate IV.—When equal horizontal semicylinders intersect, the square they cover in common is twice covered, the lines of intersection being two horizontal semiellipses crossing the square from corner to corner, and cutting each vault into four triangular segments (Plate IV, *A*). If, now, we suppose the two lower portions of each to be removed, we have left the two upper segments of each, and the four have the form of what is called a *Groined Arch*, or *Vault* (Plate IV, *B*). If we suppose the four upper triangles to be removed, the four lower ones constitute what is called a *Cloistered*, or *Closed*, *Arch*, or *Vault* (Plate IV, *C*). The Groined Vault is open on all sides, and rests upon four piers at the corners. The Cloistered Arch is closed on all sides, and rests upon the four walls that enclose it. A section through the Groined Arch shows the vaulted surface lying between the horizontal line of the ridge above and the curved line of the vault below. A section through the Cloistered Arch shows the vaulted surface bounded by the curved line of the vault above and the horizontal line of the springing below.

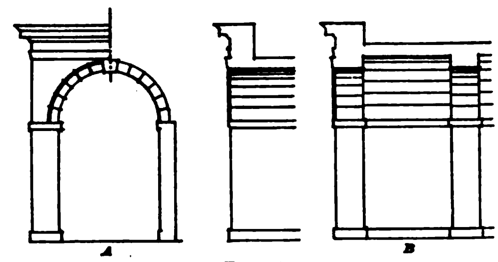


FIG. 11

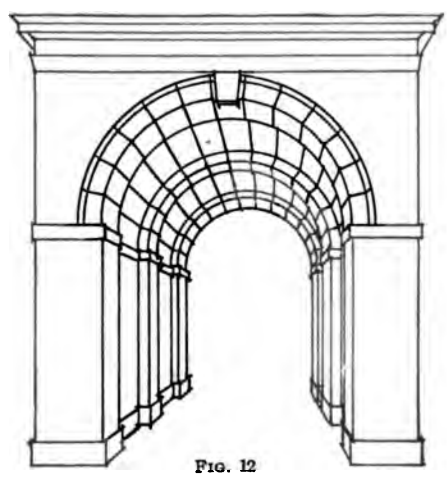


FIG. 12

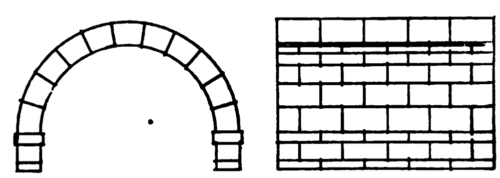


FIG. 13. ROMAN VAULT

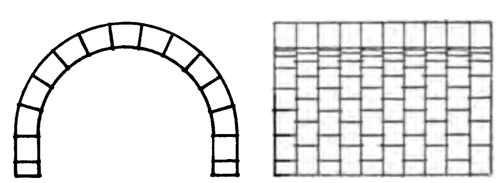


FIG. 14. BYZANTINE VAULT

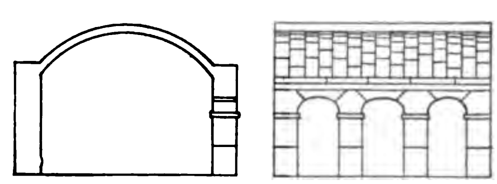


FIG. 15. CISTERN IN JERUSALEM

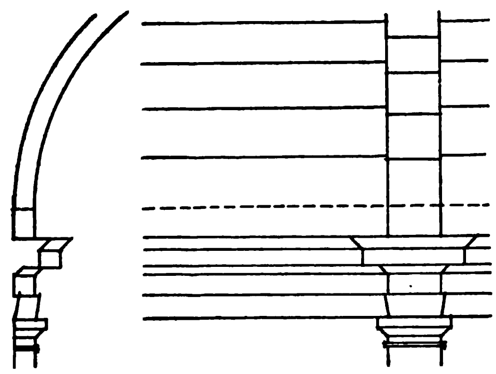


Fig. 16

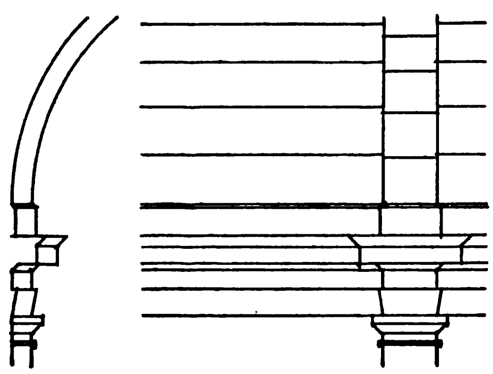


Fig. 17

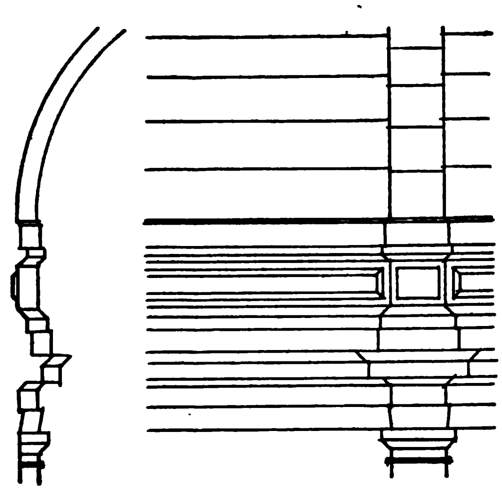


Fig. 18

The solid angle upon the elliptical line at the intersection of cylindrical vaults measures 90 degrees at the spring of the ellipse, but grows flatter as it rises. This angle is salient in the Groined Arch, and is called the *Groin*. In the Cloistered Arch it retreats, forming a reentering angle, and may be called a *Hollow Groin.*

Groined Arches, and Corridors.—Plates V and VI.—A corridor, or passage, can conveniently be covered either by a barrel vault, or by a series of groined vaults, formed by the intersection of a longitudinal barrel vault and transverse barrel vaults of the same size (Plate V, *A*). It is better not to have the groined vaults absolutely touch one another, but to have a short segment of barrel vault intervene. This space may, if desired, be occupied by a transverse arch, concentric with the longitudinal barrel vault, but of somewhat smaller radius, and supported by a pilaster at each end, as at *B*. A similar arch may be formed in the wall of the corridor, concentric with the transverse barrel arch, and also supported by pilasters, as at *C*, making on each side of the corridor a group of three pilasters.

It is to be noted in all these cases that the elliptical groin, on the line of the diagonal, springs from the hollow corner between the pilasters, that each bay of the vault is an exact square, and that the width of the corridor is the same as that of the intersecting vaults.

Plate VI shows the slightly different treatment of the same problem that presents itself when the width of the corridor is slightly greater than that of the intersecting barrel vaults. Here, as before, the successive transverse arches and the groined vaults do not quite touch. A short piece of barrel vault separates them. But as the corridor is a little wider than the longitudinal vault, the transverse vault terminates on each side in a short section of barrel vault. These sections all rest upon short sections of wall that are virtually piers, as at *A*. If the groined vaults are set a little farther apart, as at *B*, a transverse arch of smaller radius can, as before, be thrown across the passage, making groups of three pilasters, and still others, as at *C*, can be placed along the walls, making groups of five pilasters.

It is to be noted that in these cases the elliptical diagonal groin springs from the projecting corner of the pilaster, and that each bay of the vault is of the shape of a Greek cross. Also, that while in the first case, as shown in Plate V, we had first a plain wall, then a single pilaster, and finally a group of three pilasters, we begin here in Plate VI with a single pilaster, to be followed by groups of three and groups of five.

In Gothic architecture it is customary, besides these cross-ribs and wall-ribs, to strengthen the groins by diagonal ribs; but in Classic architecture this is seldom done.

Vaults of either kind are often stilted a little, just as arches are, only more so, as is shown in Fig. 16, so that the lower part shall not be hidden by the cornice below. In this

case a plinth or base may be advantageously employed, as in Fig. 17, and even a pedestal course or Attic, as in Fig. 18.

Grouped Pilasters.—Putting pilasters together in this way, three or five in a group, presents no difficulty with the Tuscan Order, in which the half pilasters may be of any convenient width or depth. But adjustments are difficult in the case of Doric Triglyphs, and in the acanthus leaves, scrolls, dentils, and modillions of the other Orders.

The triple and quintuple breaks in the outline of the piers are sometimes more numerous than are desirable in the cornice and the attic above it. In this case, the breaks may be made to terminate against the under sides of the Corona.

Arcades.—When a vaulted corridor, of either kind, is built next to the outer wall of a building, the transverse vault is often left open on that side, the outer wall being thus reduced to a series of piers, as shown in the Plates. In this case the simple square piers may be replaced by single columns (Fig. 9).

The piers with three or five pilasters on the inner side may, on the outer side, either be left plain or decorated with pilasters running the whole height of the wall, after the Roman manner (Plate VII).

Such open arcaded vaults are common in the cloisters of monasteries. But they are "Groined" Arches not "Cloistered" Arches.

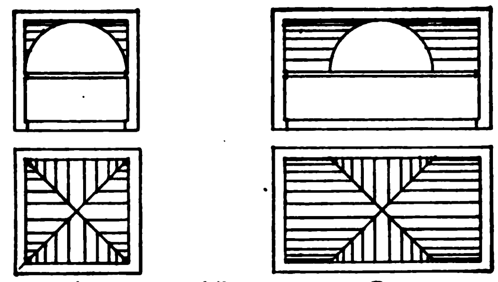
Rooms.—Groined vaults of this kind are available, of course, for covering rooms, either square or oblong. If the length of a room is an even multiple of its width, a corresponding number of square vaults will, of course, exactly cover it (see *A*, Fig. 19). If not, the difference can be made up with sections of barrel vaults (*B*, Fig. 19). Cruciform rooms may be covered with groined arches in the same manner (*A* and *B*, Fig. 20).

Since cloistered arches are closed in at the sides by walls, a series of them form just so many different rooms, and passage through them can be had only by making openings in the separating walls. These openings, whether doorways or arches, may be of any width, even as wide as the corridor. But they have to be cut in the wall (Fig. 21). They cannot, without inconvenience, go higher than the springing line of the vault. A free passage is not, as in the case of the Groined Vault, furnished by the vault itself.

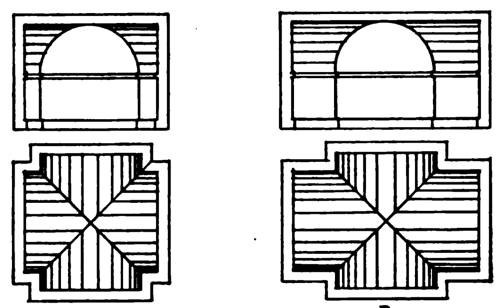
Corridors and cloisters vaulted with cloistered arches are not common. But a notable example is to be found in the upper story of the Loggia of the Vatican Palace, in which is the series of pictures called "Raffaelle's Bible" (Plate VII).

An oblong room can be covered also by the two halves of a cloistered arch, with a segment of barrel vault between them (Fig. 22). A groined arch may be used instead of a barrel vault (*B*, Fig. 19), or all three may be employed, as in Fig. 23 *A*.

Penetrations.—*Plate VIII.*—A groined vault can be lighted by windows set high up in the walls under the vaults, as in Fig. 23 *A*, and these may be made so large as to fill the whole arch. But the walls of a cloistered arch run no higher than



A FIG. 19 *B*



A FIG. 20 *B*

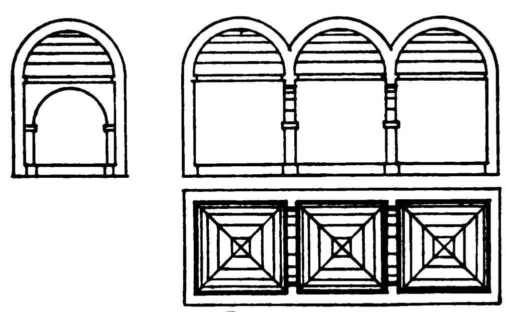


FIG. 21

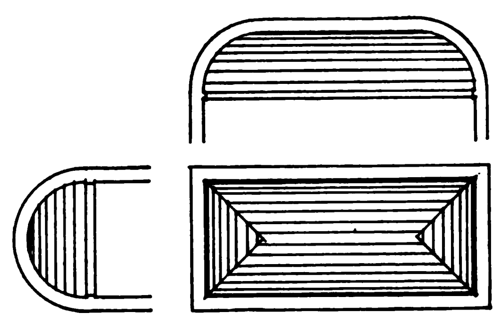


FIG. 22

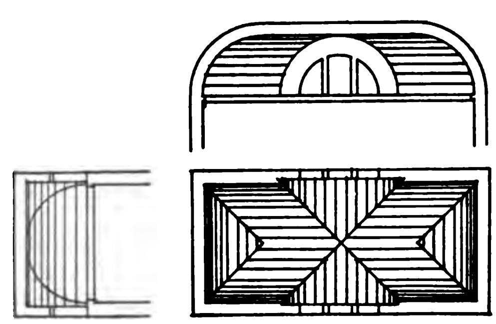
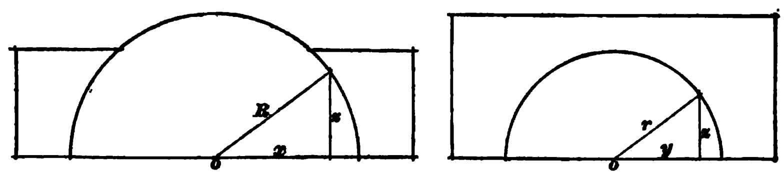


FIG. 23 *A*

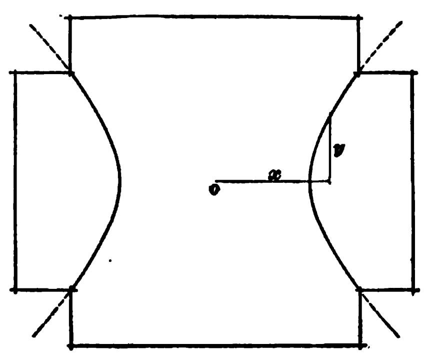
the spring of the vaults, and to get windows above that level one has to resort to a transverse vault (giving a groined arch, as in Fig. 23 *A*), or to what are called *Penetrations*. These are small barrel vaults that intersect the larger ones and make a sort of partial groining.

When two cylinders of equal radius intersect each other, as in Plate IV, *A*, the lines of intersection are ellipses lying in vertical planes, the vertical projections of which are arcs of circles, and the horizontal

A



$$1.\begin{cases} x^2+z^2=R^2 \\ z^2=R^2-x^2 \end{cases} \qquad 2.\begin{cases} y^2+z^2=r^2 \\ z^2=r^2-y^2 \end{cases}$$



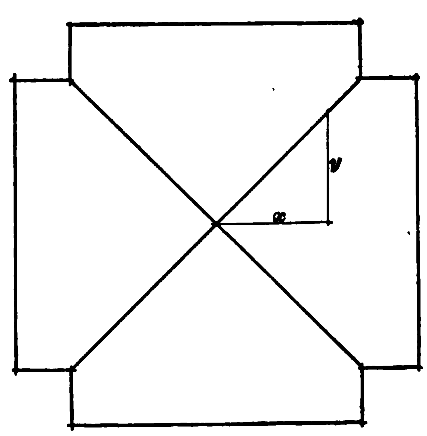
Hence:

$$3.\begin{cases} R^2-x^2=r^2-y^2 \\ x^2-y^2=R^2-r^2=C. \end{cases}$$

which is the equation of an equilateral hyperbola.

FIG. 23 *A*

B



If the two cylinders are of equal size, then $R=r$, and the equation of the horizontal projection of the line of intersection becomes

$$\begin{cases} x^2-y^2=0, \\ x=\pm y, \end{cases}$$

which is the equation of two lines lying at 45 degrees, as is also shown in figure 23 *B*.

FIG. 23 *B*

projections are straight lines, as appears in Figs. 19 to 23 and in Plate VIII, at *A*. When the radii are different, the line of intersection is an irregular curve, such as is seen in perspective at *B*. This wavy line is, as shown, a curve of three dimensions. Its vertical projections are, however, as appears in Fig. 23 *A*, arcs of circles, being, of course, cross-sections of the cylinders at whose intersections it lies, the radii of which are R and r. Its horizontal projection one might reasonably expect to be a line of double curvature. But it is, on the contrary, a ***hyperbola***, the two branches of which lie where the small cylinder intersects the large one, as is seen in Fig. 23 *A*.

At *1*, the two branches of the line of intersection appear as arcs of a circle, whose radius is R. The coordinates of these arcs are x and z, and their equation $x^2+z^2=R^2$. At *2*, the projections are arcs of the circle whose radius is r; the coordinates are y and z, and the equation is $y^2+z^2=r^2$. At *3* it appears as a curve whose coordinates are x and y, its equation being $x^2-y^2=R^2-r^2$, obtained by subtracting the second of the previous equations from the first. But this is the equation of the *Equilateral Hyperbola*.

If the intersecting cylinders are alike, $R=r$, and the equation of the line in which their intersection is projected is: $x=y$. The two branches of the hyperbola now become two right lines, as appears in Fig. 23 *B*, and also in Plate VIII, at *B*.

Since the form of the line is more noticeable than the form of the vault, it is customary, in both Gothic and Classic Architecture, to substitute for the regular surface and irregular line of intersection a regular line and an irregular surface. In place of the wavy line shown at *B*, a broken line is used, as shown at *C*. This consists of arcs of two vertical ellipses, meeting at a point. When the planes in which they lie, are, as is usual, and as appears in the figure, taken as 45 degrees with the wall below, their projections make, in plan, a right angle. The curves are elliptical arcs and are similar to the elliptical hollow groins in the corner of the vault, and their vertical projections appear as arcs of the same radius as the cylindrical vault, and look in elevation like a pointed arch.

Between these elliptic lines and the semicircular vault in the plane of the wall lies a warped or conoidal surface, which takes the place of the intersecting cylinder.

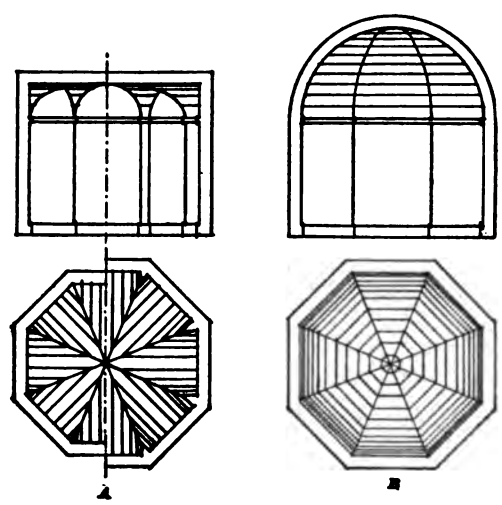


FIG. 24

If two such penetrations meet in the corner of a room, the elliptical line lies partly in a solid angle, partly in a hollow one (Plate VIII, *F*).

But if the planes in which these arcs lie are set thus at 45 degrees with the wall, and if the elements, or generatrices, of the warped surface are right lines, the element that goes from the top of the wall arch to the point where the elliptic arcs meet will pierce the vault. A portion of the line will lie within the cylindrical surface of the vault, and the warped surface will at that point be convex down. To avoid this, the generatrices, or elements of the warped surface, must be curves, convex up, as shown in the Plate at *C*.

When rectilinear elements are used, piercing the vault may be avoided, as at *D*, by making the highest element tangent to it. The vertical planes in which the curves of intersection lie will then make with the wall angles of less than 45 degrees, and their horizontal projections will make an obtuse angle with each other, as in the figure.

In either case, the points at the top of the penetrations are often, as at *C* and *D*, joined together by a horizontal molding, which divides the lower and steeper portion of the cloistered vault containing the penetrations from the upper portion, which is almost flat. This is called a *False Coved Ceiling*, since, although it is a true vault, the upper portion is nearly flat and it looks very much like a Coved Ceiling.

Coved Ceilings.—A flat ceiling surrounded with a cylindrical coving, is called a *Coved Ceiling* (Plate VIII, *E*). It is not a real vault, though it looks like the kind of Cloistered Arch with a horizontal molding just described. When

the coving has an arc of 90 degrees, with penetrations of the same radius, the result is just half a groined arch, as appears in the figure. But the coving may have a larger radius and a smaller arc, and the penetrations may also have a smaller radius than the coving, in which case they are like those of a cloistered arch, as shown at B, C, D, and E.

Octagonal Plans.—Both Groined and Cloistered Vaults may be erected upon an octagonal plan (see Fig. 24). In this case, the height of the groined arch, as appears at (a), instead of being half the width of the room, is only half the width of one side of the octagon, and the groin has the shape of a very flat ellipse. It may spring either from the hollow angle formed by the walls, or from a pier. In the octagonal cloistered arch, on the other hand, as shown at (b), the height is half the width of the room, and the hollow groins are nearly semicircular.

These octagonal vaults are often called Octagonal Domes, and are frequently somewhat pointed, as in the Cathedral at Florence (Plate XII), the radius of the vaults being more than half the width of the octagon.

ROOFS

Barrel vaults and groined and cloistered arches are sometimes, in Byzantine and Oriental Architecture, visible from the outside, but they play a small part in the exterior elevation of Classical or even of Gothic buildings, in which they are habitually covered by sloping roofs. These are generally of wood, though the vaults are sometimes loaded with masses of masonry that are brought to a rectilinear form (Fig. 25). In these cases, of course, they have to carry this weight in addition to their own, but the additional stiffness of the mass tends to prevent an increase of thrust upon the walls. Roofs of solid masonry are naturally made as light as possible, and the vaulting is carried well above the eaves, as in the figure. But wooden roofs generally lie entirely above the vaulting, the crown of which is on a level with the eaves, as shown in Fig. 26.

Gabled Roofs.—Gabled Roofs correspond in form to barrel and groined arches (Fig. 27, *A*, *C*, and *D*), and hipped roofs to cloistered arches (*B*), the valleys answering to the groins, and the hips to the hollow groins. Roofs with a flat on top correspond to Coved Ceilings, and Dormers and extra gables correspond to the different kinds of penetrations (Fig. 27 *E* and *F*).

Pyramidal Gabled Roofs.—Plate IX.—The intersecting gables of a roof are generally horizontal prisms, so that the ridges are level, and when the roofs are similar their point of intersection is at the same height as the peaks of the gables, as at *A*. But sometimes the ridges are sloped upwards and meet at a higher point, or apex, as at *B*, *C*, and *D*. As the apex is raised higher and higher, the horizontal cross-section, from four gables of equal height, is at first a four-pointed star, as at *B*, and finally becomes an irregular octagon, as at *D*; and there is an intermediate stage at which, as at *C*, it is a square or diamond, the line from the apex to the corner being at this stage neither a hip nor a valley. It then lies half-way between the peaks of the two gables, and, as appears from the figure, the slope of the ridge is parallel to that of the gables. The roof is a square pyramid set cornerwise. This kind of roof is common on the towers of Romanesque Churches in Germany, as is illustrated at *E*.

An elegant variation of the type shown at *C* is obtained by cutting off the corners so as to produce, in plan, an octagon of unequal sides, as in the towers of a church at Providence, R. I., as shown at *G*.

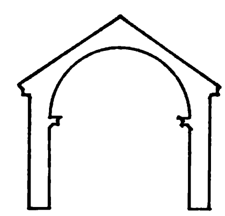


Fig. 25

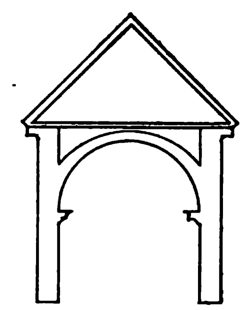


Fig. 26

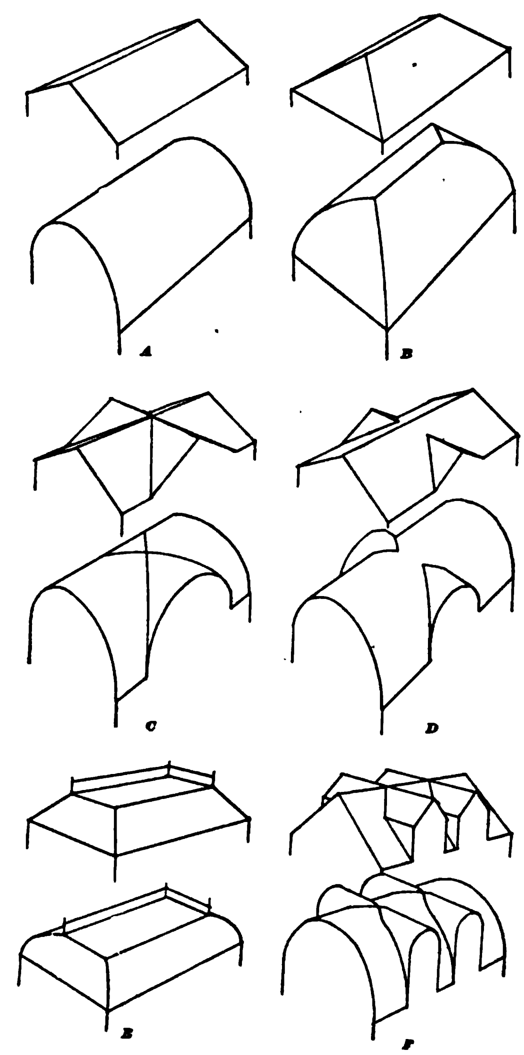


Fig. 27

When the ridges of the eight gables of an octagonal roof, like that shown in Plate IX at *H*, are sloped up to a central point, the cross-section is at first an eight-pointed star, as at *I*, and finally becomes a polygon of sixteen sides, as at *K*. Here, again, there is an intermediate stage, as appears in the figure at *J*, in which the roof has the shape of an octagonal pyramid set askew, with its sides toward the points of the gables. At this stage, the lines from the apex, or central point, to the corners are neither hips nor valleys, but lie half-way between the peaks of the gables, as in the previous example. The central point, or apex, may be found by drawing such a line.

Other Roofs.—Plate X.—Besides Hipped and Gabled Roofs, with a single slope, there are the so-called Dutch or Gambrel Roofs, or gables of two slopes, as in Plate X, at *A*, and the so-called Mansard Roofs with hips in two slopes, of either a straight or a curved outline, convex or cancave, with or without a flat on top, as at *B*. The lower pitch of such a roof is often crowned by a heavy molding or cornice, a molding or rib also decorating the hips. A cresting or railing often crowns the ridge of a roof, and the flat is generally, and naturally, surrounded with a railing, or balustrade. A truncated hipped roof, with neither an upper roof in sight nor any sort of cresting above it, looks clumsy. This is exemplified in Plate X, *C*. The lower part of the figure shows how this effect may be avoided, and the existence of the flat concealed, by means of gables.

Roofs composed of the same geometrical elements, and exactly alike in plan, may be made to vary greatly in architectural character and expression merely by changing the slope (Plate X, *D*). Variety may be obtained in the same building by using steeper roofs at one point than at another (Plate X, *E*).

Roofs of Equal Slope.—But, in general, it is most convenient, if the slope is not to vary much, not to vary it at all, adopting a uniform inclination all around, as in Plate XI. If the eaves are, as at *A*, all at the same level, the height of each roof will be proportioned to the width of the portion of the building that it covers. The valleys and hips will also be of uniform inclination, and in the plan of the roof they will, as in the figure, all lie at 45 degrees.

In laying out the plan of such a roof, it is convenient first to use only hips, finally substituting gables where they are desired. The roof may then be regarded as consisting of a principal oblong pyramid, with smaller half pyramids attached to it. The base of the principal pyramid will be the widest parallelogram that can be drawn within the outline of the building. The rest of the plan will then consist of wings, or L's, and if these are added one by one, in the order of their width, the plan of the roof, however complicated with ridges, hips, and valleys, is easily constructed. Each roof is then less high than the preceding one, and is easily adjusted to it. Figs. *B* and *C* illustrate the steps of this procedure. The principal oblong pyramid is numbered I, and the successive additions to it are numbered II and III. In drawing *B*, part of the hip *a* is obliterated, as is part of the hip *b* in drawing *C*. At *D*, the same roof is treated erroneously, the narrower wing being taken up before the wider one. The wing III comes out wider than II, and consequently higher, and accordingly will not fit against it.

If the highest peak is cut off, as at *E*, a flat is obtained. If it is cut off at the level of one of the lower ridges, as in the figure, this ridge and the flat can have crestings at the same level.

It sometimes happens, as at *F*, that a building is of such a shape that a sequence of additions to the main parallelogram, each narrower than its predecessor, cannot be arranged. Whether treated as at *G* or as at *H*, wing III comes out wider than wing II. This occurs whenever, as in this case, as appears at *F*, there are two independent crests to the roof, connected by a ridge, *R*, like a mountain with two summits. It always happens then that the second wing comes out wider than the first; that is, that III is wider than II, as at *G* and *H*. In this case, two treatments are always possible, as shown at *I*, where there is a horizontal valley, *V*, instead of a horizontal ridge, as at *F*.

This alternative is distinctly presented at *J*, where the two parallelograms that compose the plan are drawn out in full. The intersecting hips and valleys form a square, or diamond, the corners of which are marked r, r', v, v'. If the line $r r'$ is taken, the roof has a horizontal ridge, as at *F*. If the line $v v'$ is taken, it has a horizontal valley, as at *I*.

This procedure is of service in laying out the slight slopes of tinwork on a flat roof, so as to secure an even flow of water and avoid horizontal valleys.

DOMES

A vault erected upon a circular wall is called a *Dome*, or *Cupola*. It is built up of successive courses of horizontal rings, the horizontal joints being the continuous ones. The inner surface of a dome is sometimes a plain spherical surface; but it is sometimes enriched by vertical ribs, and sometimes by horizontal moldings, following the lines of the horizontal joints, and sometimes by both, which gives a series of trapezoidal panels, as in the Pantheon at Rome (Plate XII).

Domes are sometimes erected upon square or octagonal plans, in which the corners, which the dome does not cover, are covered by *Pendentives*. These are either diagonal arches, as shown in Fig. 28 *A*, or, more commonly, spherical triangles, as shown in Fig. 28 *B*, and also in Plates VII and XV.

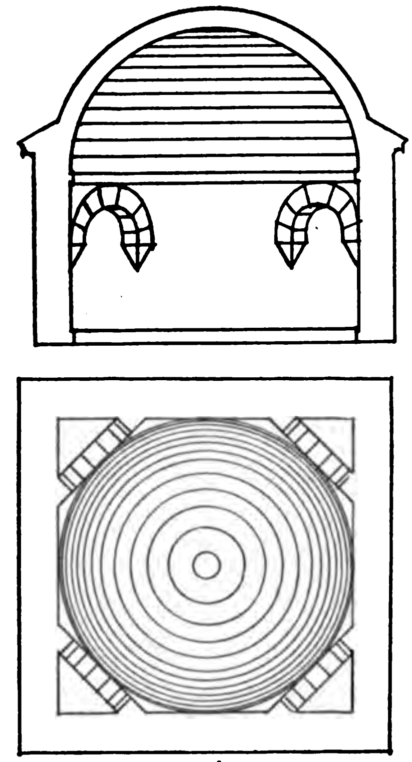
There are three kinds of domes with spherical pendentives. In the first kind, the pendentives are a portion of the same sphere as the dome they support, as at *A* and *B*, Fig. 29, and the dome is flat, or segmental, having, on a square plan, a vertical arc of only 90 degrees. In this case, it is generally separated from the pendentive by a horizontal molding, as at *A*. But this is sometimes omitted, in which case the pendentive is called *continuous*, as at *B*, and in the lower story of the Loggia of the Vatican (Plate VII).

In the second kind, the pendentive is discontinuous, the dome being generally a full hemisphere, constructed with a radius less than that of the sphere of which the pendentives form a part (see Fig. 28 *B* and Fig. 29 *C*).

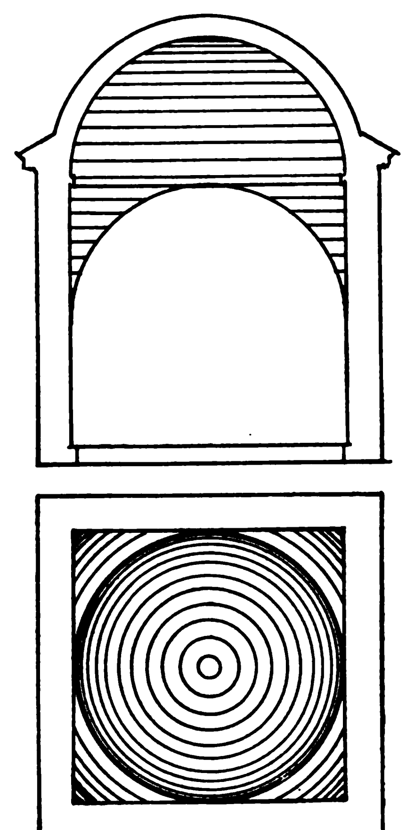
In the third kind, a vertical cylinder, called a *Drum*, is erected upon the pendentives, as at *D*, and the dome rests upon that, as upon a circular wall, as in St. Peter's (Plate XII).

Domes are sometimes lighted by small dormer-windows, which are frequently circular; sometimes by rectangular windows in the drum, as at St. Peter's; sometimes by an eye, as in the Pantheon in Rome; or by a *lantern*, which is a cylindrical or octagonal structure resting on the summit, and nearly closing the eye. But such a lantern gives very little light.

Unless a dome is very large, the height of the drum required to make it conspicuous from without, gives an excessive height within. It is customary, accordingly, to insert a hemispherical ceiling, or second dome, at a lower



A



B

Fig. 28

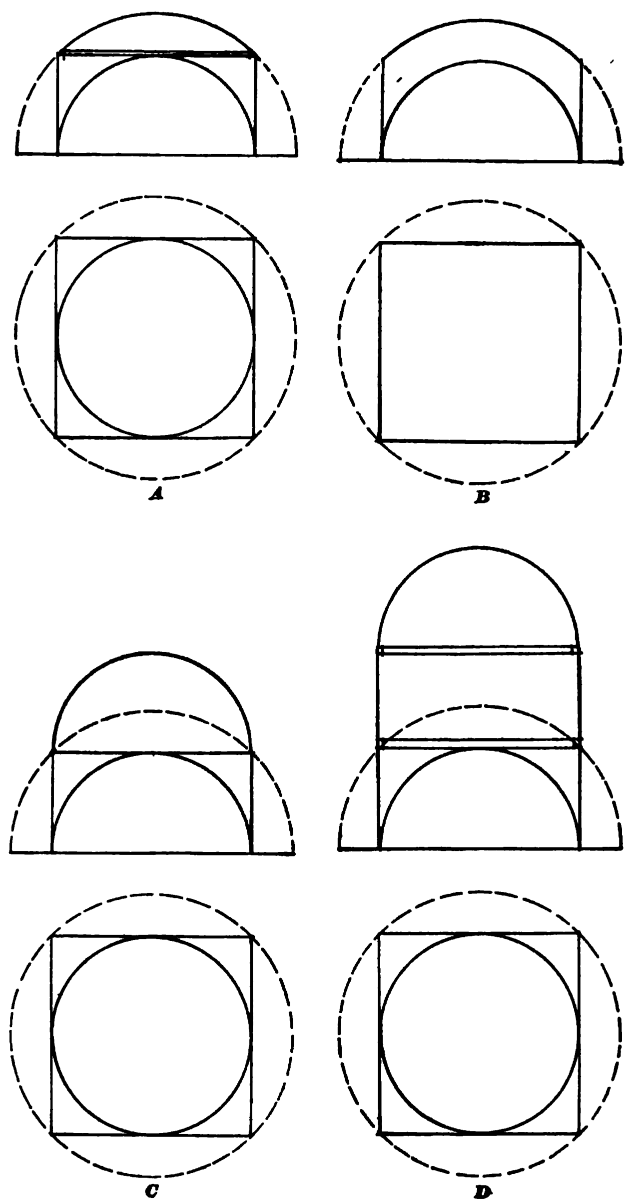


FIG. 29

point within, as is done at St. Paul's in London, in the Capitol at Washington, and in the Chapel of the Invalides in Paris (Plate XII).

Outside, as within, domes are sometimes plain, sometimes enriched with vertical ribs and with small dormers. Horizontal ribs are less common. The drums are often strengthened by buttresses, as at St. Peter's, or by circular colonnades, as in the Pantheon in Paris, or by both, as in St. Paul's Church in London (Plate XII).

Octagonal Domes.—Octagonal Domes, which are really cloistered arches, are treated in the same way. Both octagonal domes, as at Florence, and circular domes, as in Rome, London, and Paris, are frequently made more or less pointed. This gives greater height and a more graceful outline with less horizontal thrust. But it is frequently overdone.

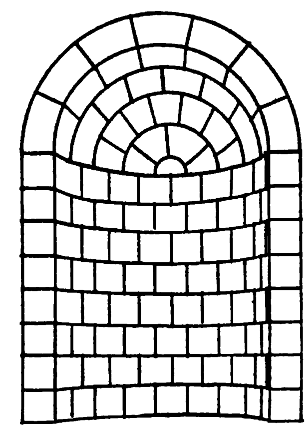


FIG. 30

Even where there is no drum, the dome is often stilted a little within, to clear the cornice at the spring, just as is done with arches and vaults, and, as with them, a high plinth or even an attic is sometimes used.

Half Domes and *Niches*, large and small, are of frequent occurrence, both outdoors and within, where they often close the openings in the arches that support groined vaults or domes. On a small scale, they serve as receptacles for statues and busts (Plate XII). In niches, the vertical joints are sometimes made continuous, instead of the horizontal ones (Fig. 30).

DOORS AND WINDOWS

Doorways are generally about twice as high as they are wide, or, as is said, two squares high. Common doors are three or four feet wide and six or eight feet high. The opening is covered, and the wall above is supported, either by a straight beam of stone or wood, called the *Lintel*, or by an arch. But as the opening is generally closed by a *door*, in one or two valves, and it is more convenient to have this rectangular, even when an arch is employed, a lintel is often used below the arch, on a level with the Impost, to receive the door, and another horizontal beam, or *Threshold*, is put in at the bottom, so that it may fit tight and yet swing clear.

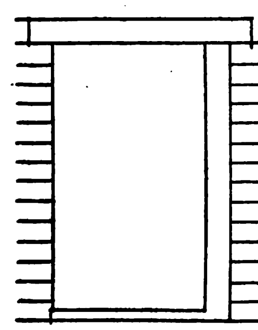


Fig. 31

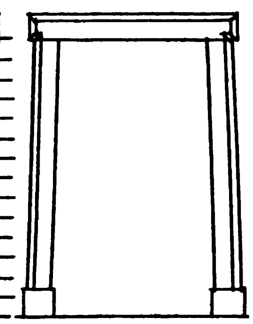


Fig. 32

The sides of the doorway are called the *Jambs*. They are sometimes built up in courses, like the rest of the wall, and sometimes consist of a single stone (see Fig. 31). In either case, they were anciently made to slope inwards a little, so as to diminish the span of the lintel (Fig. 32). The joint around the edges of the lintel and of the jamb post is often emphasized by a raised molding, like that upon an architrave, and the lintels are sometimes, like an architrave, divided into two or three bands. This treatment is habitually carried down the jamb, which is then also commonly called an architrave. When the lintel is so long as to overrun the door posts, the projections are called *Crossettes* (see Fig. 33 *A*, *B*, *C*, and *D*). The inner band does not show a crossette. The neatest arrangement is to have the outer band with its molding just as wide as the inner band, as shown at *A*, Fig. 33. Then the crossette comes entirely on the lintel. But this is not very common, and the crossette is often cut by the joint, part of it coming upon the door post (Fig. 33 *B*). One way to avoid this is to cut out the under side of the lintel to receive the doorway, as shown at *C*, Fig. 33. What is called a *Double Crossette* is shown at *D*, in the same figure.

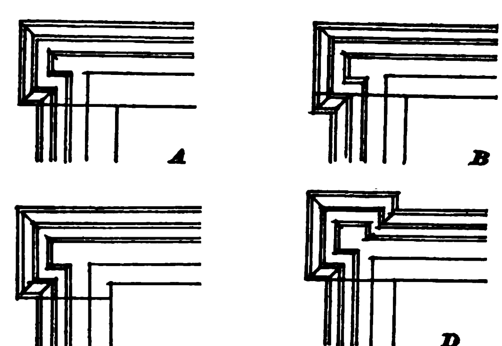


Fig. 33

The doorway may be further enriched by adding to the architrave, the frieze, cornice, and pediment, or attic, of a full order (Fig. 34 *A* and *B*).

Still greater richness is secured by slightly lengthening the corona of the entablature, and supporting the ends upon brackets, or consoles, which come down just outside the door posts, and, in turn, often rest upon a tall, shallow strip called a *chambranle;* this is often paneled. The type of this doorway is that of the Church of San Damaso, by Vignola, in the façade of the Palace of the Cancellaria at Rome (Plate XIII, *A*).

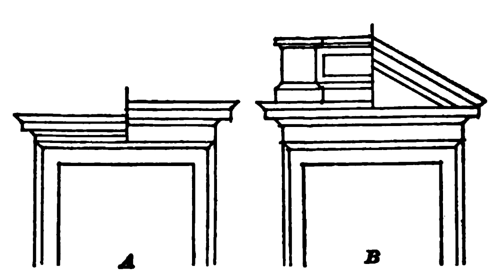


Fig. 34

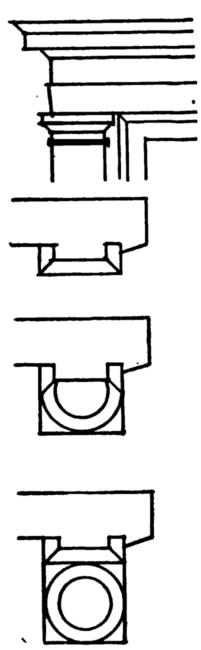


FIG. 35

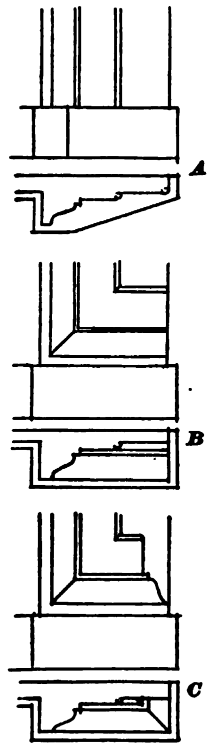


FIG. 36

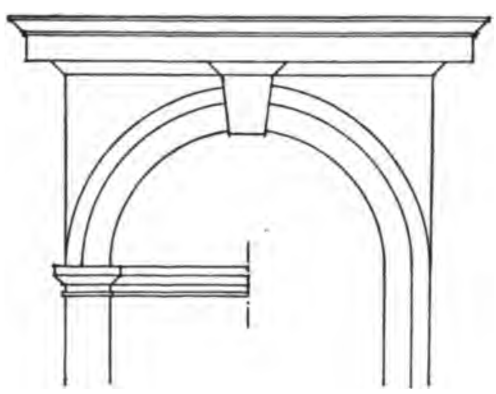


FIG. 37

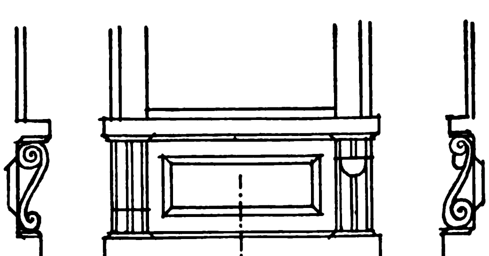


FIG. 38

But sometimes the door post is treated as a pilaster and furnished with a cap and base (Fig. 35). The molding at the top of the lintel is then not carried down at the ends, but is returned upon itself. In this case, also, a full entablature may be employed, and the treatment made still richer by setting in front of the pilaster a three-quarter column or a full column. This is often set well in front of the pilaster, so as to make a shallow porch. But in these cases, the doorway is generally furnished with an independent door jamb and lintel, as shown in the figure.

At the bottom of the door post, the moldings are sometimes received upon a block slightly beveled to conform to their outline, and whether this happens or not they are often turned inwards toward the doorway and then sometimes again returned upon themselves, as in Fig. 36, *A*, *B*, and *C*.

In Northern Italy, the cornice over a doorway, instead of carrying an angular pediment, or a curved pediment, with an arc of 90 degrees, is often surmounted by a semicircular pediment, the extrados of which extends as far as the ends of the frieze below it (Plate XIII, *B*).

Doorways with semicircular heads are generally treated like a Roman Arch (Plate XIII, *D*). But sometimes the pilasters are omitted, as in Fig. 37. The cornice then rests only upon the keystone and the spandrels. In either case, the impost is often carried across as a lintel.

Windows.—The treatment of windows differs from that of doors chiefly because a window sill is set higher from the ground than a threshold, and while a doorway is, in general, rectangular, and higher than it is wide, windows may conveniently be made of other shapes. Moreover, while doorways are in general single, and isolated, windows habitually occur in a series, more or less connected with one another. Windows also are often divided by horizontal bars, called *Transoms*, and by vertical ones, called *Mullions*.

Window Sills.—A long window, coming down to the floor, has a sill like a threshold, though thicker. But the sill is generally set two or three feet above the floor, and in that case often has a panel beneath it, and the window jamb is often supported by a console, or an inverted console (Fig. 38). But sometimes the architrave is carried across the bottom of a window, with or without crossettes at the lower corners. This is more usual when the window is square, or wider than it is high (Fig. 39).

Circular and oval windows are called *Oeils-de-Boeuf* (Fig. 40). Semicircular or segmental windows are naturally employed under arches, and are divided by radiating, or more frequently by vertical, mullions (Figs. 41 and 42). Windows that extend through several stories generally have wide paneled transoms at the floors (Fig. 43). The window sill is often continued from window to window, forming a stringcourse, with or without moldings beneath it, and a continuous pedestal often connects the panels below the window sills,

forming a sort of basis upon which the separate windows stand (Fig. 44). The entablature above the windows is sometimes carried along in the same way, and in this case the enclosed rectangular wall space between the windows is often paneled (Fig. 45). But connecting the lintels without connecting the sills leaves the windows "hanging" (Fig. 46).

Sometimes the windows are treated with a simple architrave, or, as in the Hotel de Ville at Paris, with none at all, and the architectural embellishment of the series is bestowed entirely upon the wall spaces between them (Plate XIII, *E*).

Round-headed windows are treated in the same way as round-headed doors. But the semicircular heads are sometimes, especially in Northern Italy, occupied by a species of tracery, supported by one or two mullions. In this case, the larger semicircle is much crowded; it is usually somewhat stilted (see Plate XIV, *F*).

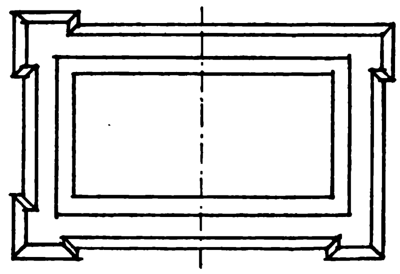


Fig. 39

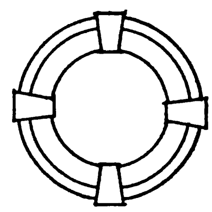


Fig. 40

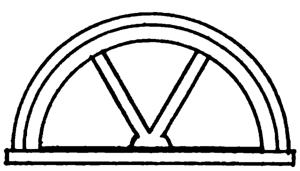


Fig. 41

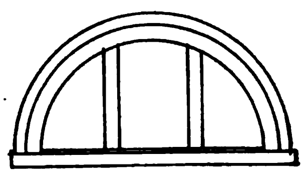


Fig. 42

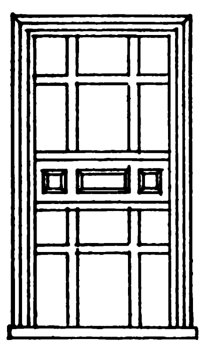


Fig. 43

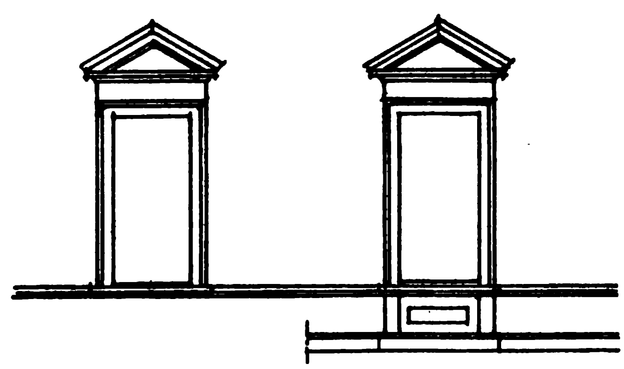


Fig. 44

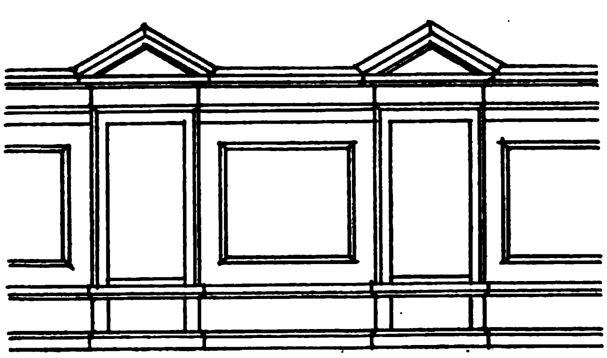


Fig. 45

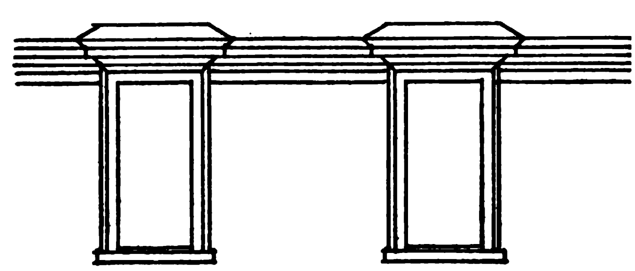
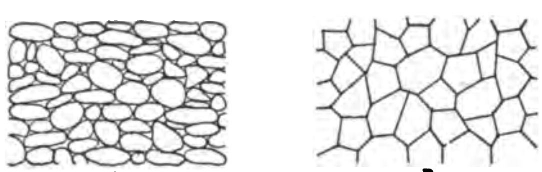
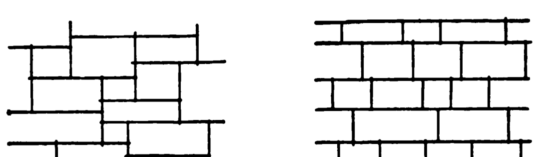


Fig. 46



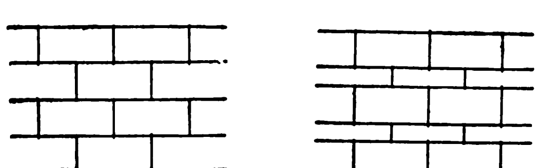
A B

Fig. 47



A B

Fig. 48



A B

Fig. 49

WALLS

The aspect of Stone Walls differs according to the kind of masonry employed. In rubblework (Fig. 47 *A*), the size and shape of the stones and the direction of the joints are entirely a matter of accident; in "Cyclopean work" (Fig. 47 *B*), the stones are large, are of nearly uniform size, are bounded by right lines, and are carefully fitted together, but the joints run in every direction; when, as is shown in Fig. 48 *A*, the joints are horizontal and vertical, and the separate stones are of course rectangular, they are then sometimes regular in size, but laid in courses of varying height, as at *B*, Fig. 48, or of equal length, and all of the same height, as in the Roman *Opus Quadratum*, shown at *A*, Fig. 49. Sometimes the courses are alternately wide and narrow, as shown at *B*, Fig. 49.

Rustication.—In all these cases, though the jointing conspicuously affects the character of the surface, the joints hardly count as an architectural feature, unless, as is often done where the stones have a regular shape, they are emphasized by leaving the face of each stone rough, or by beveling the edges of each stone, or by cutting a chisel draft around it, the center being raised. This treatment is called ***Rustication.*** It is sometimes applied to the whole surface of a wall (Fig. 50), but is more frequently used in arches, where it emphasizes the separate voussoirs (Fig. 51), and upon the ***quoins*** at the corners of buildings (Fig. 52). But these, ordinarily, like the stones of the rest of the wall, are regarded as constituting a plane and uniform surface, as is illustrated in Fig. 3.

Quoins.—Rusticated quoins are sometimes all made of the same size (Fig. 53 *A*), sometimes alternately large and small (Fig. 53 *B*), but all square in plan. In this case, it is best to have the top one and the bottom one large, as shown. But when, as is often done, they are oblong and all of the same length, but laid with the long side first on one side and then on the other (Fig. 53 *C*), this of course cannot be secured.

When a chisel draft is used, it is best, if the stones are all of the same length, to cut it only on the ends and upper edge, as in Fig. 53 *A*, since this both protects the joint and renders it inconspicuous. But if the stones are alternately long and short, this is impracticable, as appears from Fig. 53, *B* and *C*, and the four edges must be treated alike.

The surface of the stones is sometimes left rough, retaining the quarry face. Sometimes it is cut smooth, or roughly tooled (Fig. 54 *A*); sometimes carved either with an irregular pattern, called *vermiculation*, as if worm-eaten (Fig. 54 *B*), or with decorative patterns (Fig. 54 *C*). The former is more usual on quoins, the latter, as in the Louvre and Tuileries, on the drums of columns. Sometimes this surface is pulvinated, (Fig. 54 *D*), and sometimes beveled (Fig. 54 *E*), and the alternate stones sunk (Fig. 54 *F*). In either case, a chisel drift may be added around the edges.

The vertical pile of quoins, one over another, is called a *Chain*.

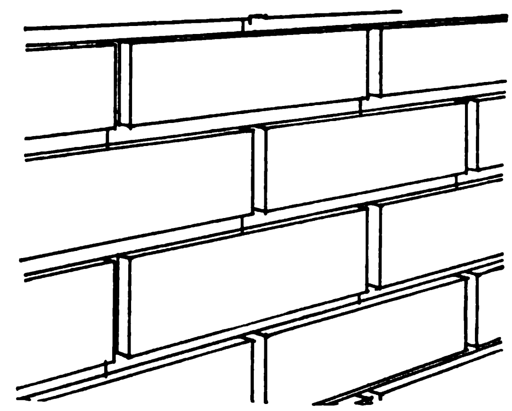


Fig. 50

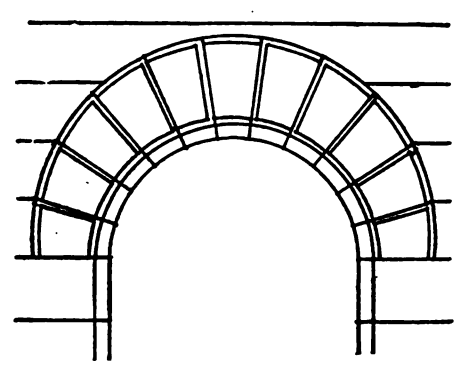


Fig. 51

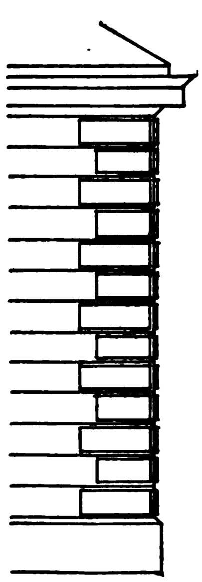


Fig. 52

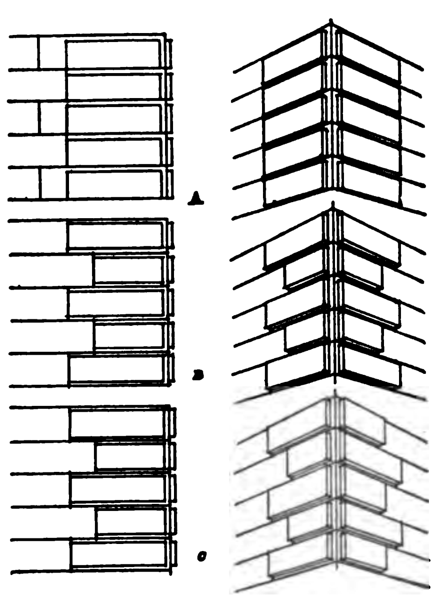


Fig. 53

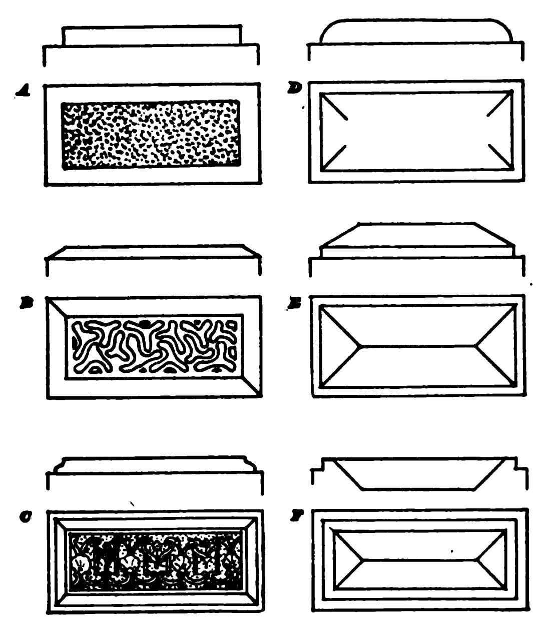


Fig. 54

Florentine Arches.—Voussoirs sometimes terminate at the extrados of the arch, as in Fig. 55 *A*, and the extrados is then sometimes made pointed, as at *B*, which is called a *Florentine Arch*, the joints sometimes meeting those of the wall, an adjustment which may have suggested this treatment (Fig. 55 *C*). But frequently the outer end of each voussoir is cut with both vertical and horizontal joints, so as to bond into the other masonry of the wall (Fig. 55 *D*). The keystone, and sometimes the two voussoirs on either side of it, is then generally made of extra length, as in the figure. Voussoirs are sometimes made angular, with a *lug* (Fig. 55 *E*); but this is apt to break off.

If a flat arch (Fig. 56) is built with rusticated voussoirs and the jambs are also rusticated, the beveled edges come badly together at the corners, as is seen at *A*. This may be avoided by making the *Skew Back*, as the corner stone is called, either longer (Fig. 56 *B*) or, preferably, higher (Fig. 56 *C*), or by having a chisel draft all around the stone outside the raised surface (Fig. 56 *D*).

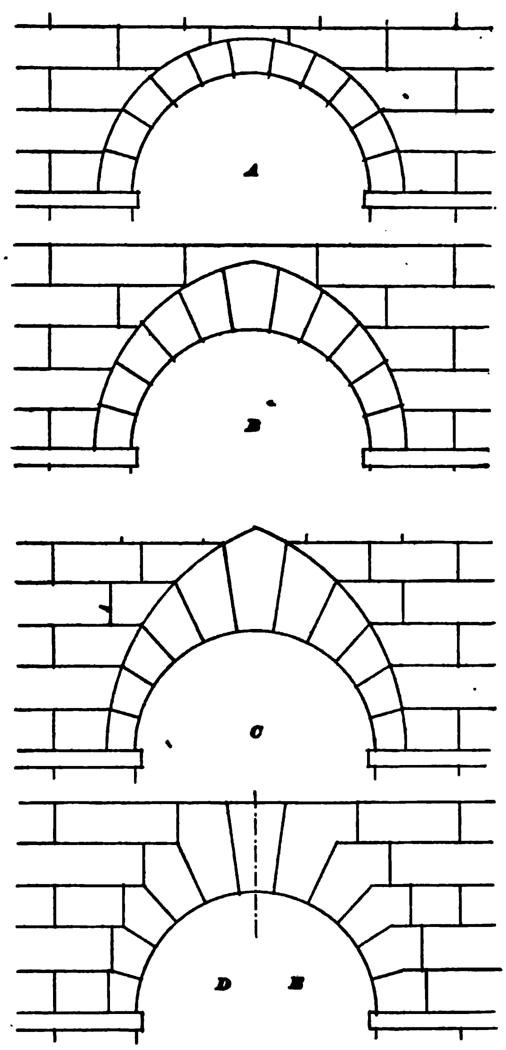


Fig. 55

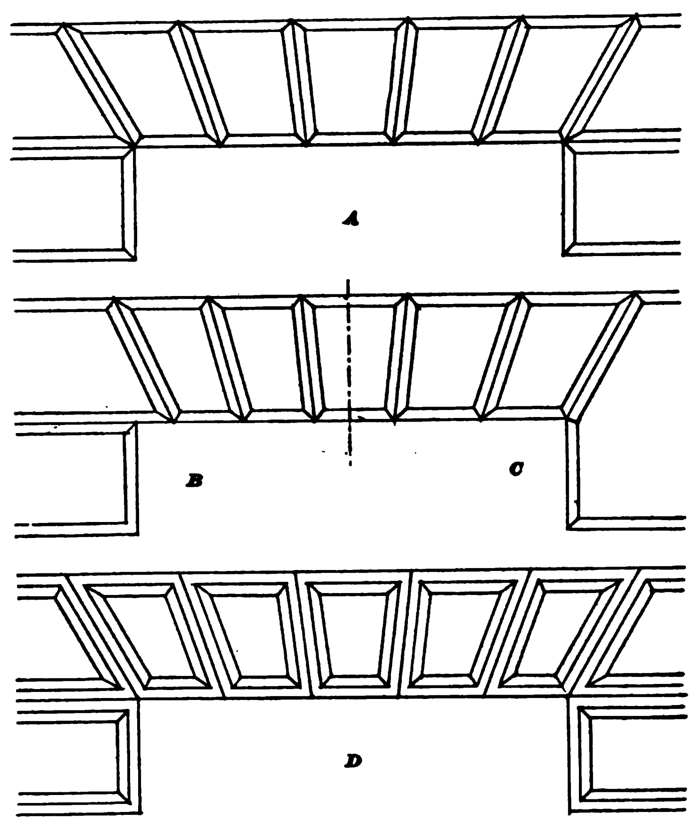


Fig. 56

WALL TREATMENT

The contrast between the richer and more broken surfaces presented by columns, entablatures, string-courses, doors, windows, and rusticated groins, and the plain wall surface that separates them, is one of the most effective elements in architectural composition, and it is enhanced by making the masonry of the wall as smooth as may be, and even concealing its natural roughness by stucco or plaster. But it is sometimes desirable on the contrary to enrich the wall surface by encrusting it with architectural details. Examples of this are shown in Plate XIV.

In Classical Architecture, as in other styles, the principal decorative details are features that were originally used for structural purposes, such as columns and entablatures, arches and piers, pediments and pedestals, doors, windows, and niches. All these things have been brought into such good form that they have a decorative interest, quite independent of their structural value. When used upon a wall, they sometimes constitute the main fabric, the wall behind them being only a screen, or *Wall veil*, carrying only its own weight. But sometimes the wall is the real structure, the architectural features being, as it were, carved upon its surface. These, in serious work, closely conform to the forms and proportions that are imposed upon real constructions by considerations of strength and stability. But being in fact only a surface decoration, they are not really bound by such restrictions, and great freedom is sometimes used, especially when the architecture is represented in paint or plaster, as at Pompeii. During the period of the Renaissance we find, not infrequently, especially in the baroque style in France and Germany, and the Churriguresque in Spain, and the Elizabethan and Jacobean periods in England, architectural forms and combinations executed in stone that would not stand up if unsupported by the wall behind them.

It is now a generally received maxim that architectural forms should be suggested by the materials and methods of workmanship employed in producing them, that forms originating in woodwork and carpentry, for example, should not be imitated in stone, nor arches and vaults in wood. It is certainly agreeable to have this rule obeyed. But to regard it as embodying an essential principle of art is to condemn most of the historical styles, and to disparage almost all architectural monuments. For the Egyptian and Greek buildings embody in stone forms that arose and were brought to perfection in cheaper and more easily worked materials, such as clay and wood. It is only in the Gothic buildings of the Thirteenth Century and in the woodwork of Switzerland and Sweden that this dogma is fully exemplified.

In the decoration of walls, pilasters, rather than columns, naturally play the chief part, sometimes accompanied by a pedestal course, or by an Attic, or by both. The wall surfaces between the pilasters are often occupied by a second and smaller order, surmounted by an entablature, or merely by a string-course. Either order may carry pediments, and the lower one may carry arches, after the manner of a Roman Arch or a Palladian Motive. The spaces remaining may then be occupied by niches, with round or square heads, with or without pediments, or by panels, with or without crossettes. Any of these may be cut through to make a door or window.

When the wall is regarded as only a thin screen, its thickness may be reduced by sinking the whole surface a little, leaving only plain horizontal and vertical strips all around, like the rails and stiles of a door. The center of the enclosed space is sometimes raised in like manner. The effect of this treatment is simpler and more elegant if no moldings are employed.

The decoration of wall surfaces with colonnades and arcades (large and small), pediments, panels, and niches, is exemplified in Plate XIV, *A* to *X*. This treatment is applied to both interior and exterior walls, bays, and pavilions.

In the first six figures, from *A* to *F*, there is at the bottom a continuous pedestal, or die, sometimes called a *Dado*, and at the top a similar feature, like an attic, resting upon a string-course, which has the shape of an entablature. Sometimes both features are employed, as here, and in the six figures of the third row, from *M* to *R*. Sometimes the attic is omitted, as in the fourth row of figures, from *S* to *V*, and sometimes both, as in Figs. *W* and *X*, and in the second row from the top, from *G* to *L*. The employment of an attic without a pedestal course is less common.

The main wall surface is sometimes left plain. Sometimes, as at *A*, it is decorated with panels, raised or sunk, with or without moldings. Sometimes, as in the other figures of this series, it is treated with single or coupled pilasters, which may, as in Fig. *C*, carry a pediment in the attic. These pilasters are sometimes, as in Fig. *B*, flanked by narrow strips of wall, which are continued across under the entablature, making the pilasters look as if planted upon a broad shallow pier, and making the wall surface between them look like a sunk panel. This is, as has been said above, an effective treatment. Similar piers, but narrow, like pilasters without bases or caps, with sunk panels between them, are often used without pilasters, as in the lower part of Figs. *I* and *J*.

In Fig. *C*, the attic is occupied by a pediment, and the dado, as in the other figures, by pedestals.

In Figs. *D*, *E*, and *F*, a smaller order of pilasters is interposed between the larger ones, supporting a string-course and attic, which in Fig. *D* is occupied by the sunk panels and plain narrow piers just described. In Fig. *E*, it is occupied by a pediment, and in Fig. *F*, by a still smaller order of pilasters with a circle or Oeil-de-Boeuf, between them, as in the front of the Opera House in Paris.

In the second row of figures, from *G* to *L*, there is neither pedestal course nor attic, and the wall is treated with arcades instead of with colonnades. In Fig. *G*, the arches spring from piers, and both the wall space beneath the arch and the pier itself are occupied by a round-headed panel, or niche. In Fig. *H*, the impost of the piers is carried along beneath the arch, and all the surfaces are decorated with panels. In Fig. *I*, the impost takes the form of an entablature of two members, without a frieze, and is supported by pilasters, all the surfaces being paneled. In Fig. *J*, there is no pier, a single pilaster carrying the arch, and in *K* the wall surface beneath the arch is occupied by a pediment and pilasters, a treatment equally possible when the arch is, as in Figs. *G*, *H*, and *I*, carried upon piers. In Fig. *L*, a smaller arcade, with still smaller pilasters, supports the string-course. Here, of course, the smaller impost need not be continued between the pilasters.

In the third series, from *M* to *R*, a smaller colonnade is introduced beneath the arches, as was done in the first series between the pilasters. This combination presents the familiar features of the so-called Roman Order, as used by the Romans in their Triumphal Arches, with pedestals below and an attic above, the piers being decorated with pilasters, and the impost of the arch continued between them. In Fig. *M*, the surface of the piers is paneled; in Fig. *N*, the spaces between the pilasters is occupied by narrow arches starting from the impost; in Fig. *O*, these smaller arches are beneath the impost line, and in Figs. *P* and *Q*, the arch space is, as in Figs. *E* and *K*, occupied by a pediment resting upon pilasters. In Fig. *Q*, the large pilasters that support the entablature are replaced by two smaller ones, one over the other. In Fig. *R*, a large arch rests upon short pilasters and has a smaller concentric arch within it, resting upon similar pilasters, all the wall spaces being paneled.

The fourth series of examples, from *S* to *X*, are based upon Palladio's Motive, as shown at *S*. Here the pier and impost of the regular Roman Order, as shown in Fig. *M*, are replaced by a small pilaster and an entablature of one or two members. Fig. *U* shows the form of window treatment common in Florence and Venice, which has already been illustrated in Plate XIII. This and the figures that follow are derived from Medieval precedents. Other combinations of these elements can easily be devised.

Pilasters.—When used in conjunction with columns, pilasters and piers often diminish in size from bottom to top by a gentle curve, just as the columns do. They have both Diminution and Entasis. This is the most convenient way, though the slope of the square angle seems excessive. But when they stand alone, they look better if made straight, with parallel sides; and even when used with columns, straight pilasters are preferred, in spite of the difficulties of adjustment that the difference of shape necessarily involves.

Fig. 57 *A*, *B*, and *C* shows three ways of treating the pilaster when coupled with a column. In Fig. 57 *A*, the lower diameters are the same, and since the diameter does not diminish, its upper diameter projects one-twelfth of a diameter beyond the line of the column and of the frieze above it. In Fig. 57 *B*, the upper diameters are of the same size and are in line with each other and with the frieze above, but the lower diameter of the column

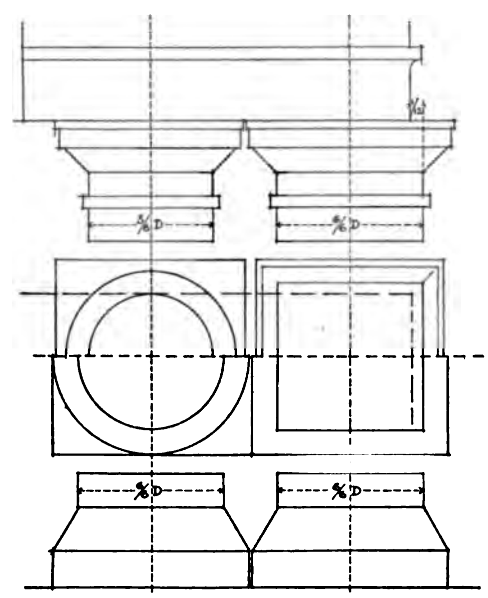
projects one-twelfth of a diameter beyond those of the pilaster. The diameter of the pilaster as seen in elevation is less than that of the column; but, when looked at diagonally, as it generally is, it looks quite as large, and a pier looks larger. The discrepancy in the plinths can be avoided by giving the moldings of the base of the pilaster more boldness, or those of the columns less, or by doing both.

In Fig. 57 *C*, the pilaster measures eleven-twelfths of a diameter, instead of either six-sixths, or five-sixths, as in *A* and *B*. This reduces the discrepancies to one twenty-fourth of a diameter, as in the figure.

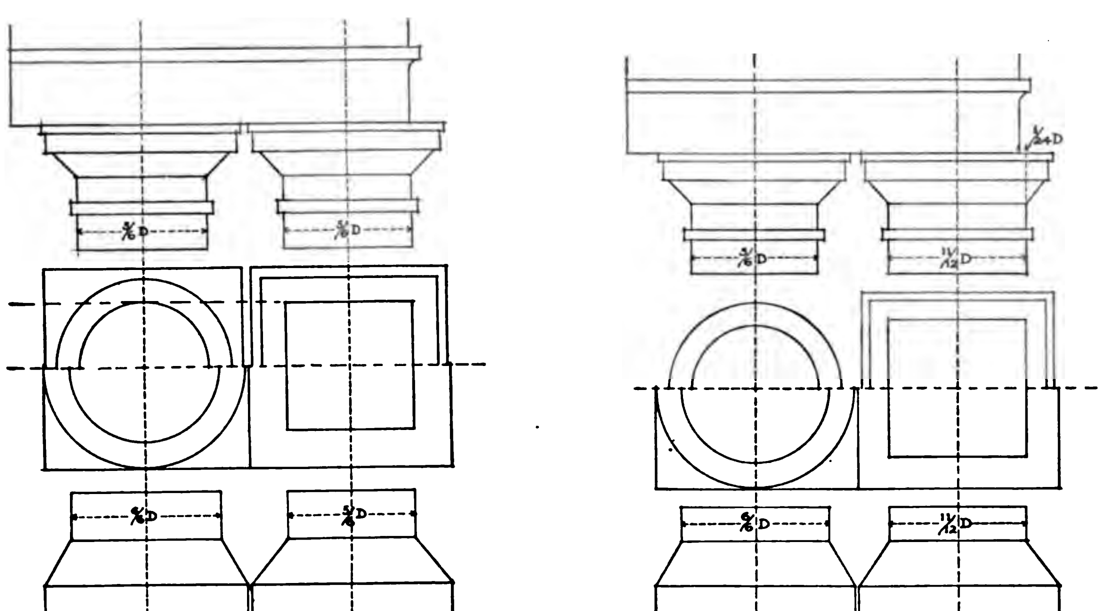
Since, in the Doric Order, the triglyph over the corner column or pilaster is only half a diameter wide, a fragment of a metope one-sixth of a diameter wide regularly intervenes between it and the end of the frieze. But in the Library of St. Mark at Venice (see Fig. 58), Sansovino increased this dimension to three-eights of a diameter, or half a metope, supporting the corner by a huge pilaster, or pier, and then planted upon each outer face of this pier a shallow pilaster of the usual width, directly under the middle of the triglyph above. The pier is set back a little, so as to bring the face of this pilaster in line with the upper diameter of the adjacent column. A somewhat similar treatment is given to the Ionic order in the second story.

The object of this device, which has been much admired, in spite of the awkward way in which the pier is cut off at its inner corners, was to get a full half metope.

In the Cathedral at Brescia, the double corners of the piers under the central dome are occupied by Corinthian columns flanked by pilasters, the columns being on the corners. The pilasters do not diminish, while the columns do. The entablature is set in line with the face of the pilaster; but when it comes to the corner, instead of continuing in that plane, and overhanging the column, it breaks back about one-twelfth of a diameter, to the line of the upper end of the shaft. This break is carried up through the entire cornice (Plate XV).



A



B *C*

FIG. 57

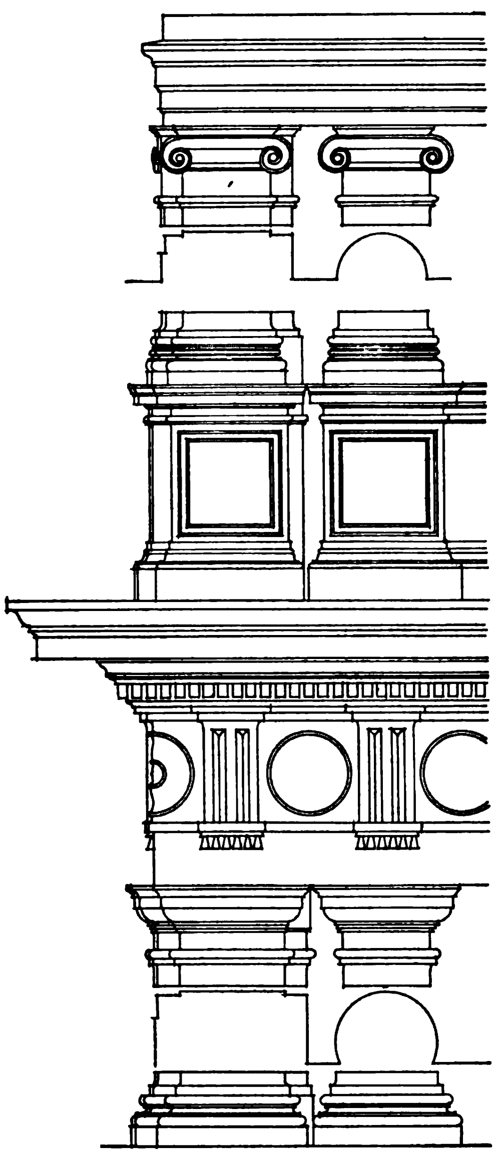


Fig. 58

Pilasters may be placed where they mark the position of transverse walls or partitions; or at the ends of a wall, where they serve as a terminal feature in the architectural composition; or they may be set at any intermediate point where they divide the surface into well-proportioned spaces.

Pilasters of the Tuscan, Ionic, and Composite Orders can be set at any points that are, for any of these reasons, desirable ones. But in the Doric Order they must be set directly beneath a triglyph and mutule, and in the Corinthian Order it is better to have the pilasters directly beneath modillions. This means that the distance apart of Doric pilasters, on centers, must be a multiple of one and one-fourth diameters; and of Corinthian pilasters, a multiple of two-thirds of a diameter.

But coupled Doric pilasters, or columns, on account of the width of their bases, have to be set a diameter and a third on centers (see Fig. 59), the metope being made ten-twelfths of a diameter wide, or five-sixths, instead of nine-twelfths, or three-fourths, as usual. Coupled Corinthian pilasters, also, on account of the width of the capitals, cannot be less than a diameter and a half on centers (Fig. 60). The modillions between their axes are then set nine-twelfths of a diameter, or three-fourths, on centers, instead of eight-twelfths, or two-thirds, as usual. The dentils and interdentils are also increased in width by one-eighth of their own width, being one-eighth and one-sixteenth of a diameter in width, instead of one-ninth and one-eighteenth, and three-sixteenths of a diameter on centers, instead of three-eighteenths, or one-sixth, as usual.

In the Ionic Order (Fig. 61), and in Vignola's Composite Order (Fig. 62), coupled pilasters or columns present no difficulty. Their distances apart on centers is a diameter and a half, which gives room for exactly nine Ionic dentils one-sixth of a diameter on centers, or for six Composite dentils one-fourth of a diameter on centers.

External Angles or Corners.—At the end of a wall, an external angle or corner may be plain, as in Fig. 63 *A*, or it may be fortified by pilasters on each face, as in Fig. 63 *B*, *C*, and *D*. These may be united so as to form a square corner pier, as at *B*, or meet in the corner as at *C*, only the capitals uniting; or each may be set back from the corner a little way, as at *D*, so that the capitals are entirely separated. The cornice generally breaks around the angles thus formed, but the architrave and frieze often do not, as in the figure. Sometimes, as at *E*, only the bed-mold of the cornice breaks, the corona being carried along without interruption and receiving the broken bed-mold under its soffit. But unless the projection of the pilasters is exceptionally small, this gives the corona an excessive prominence when seen across the corner, as is shown at *F*.

The architrave generally overhangs the wall by the depth of the pilaster, but sometimes, especially when the pilasters

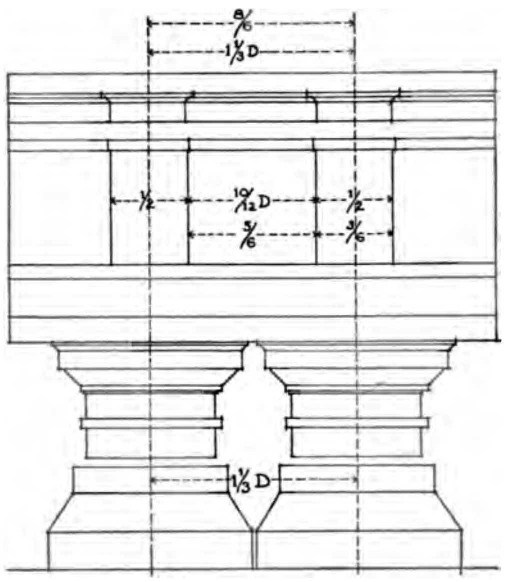


FIG. 59

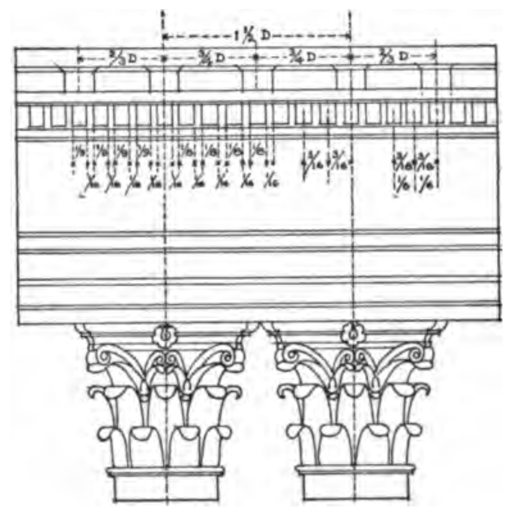


FIG. 60

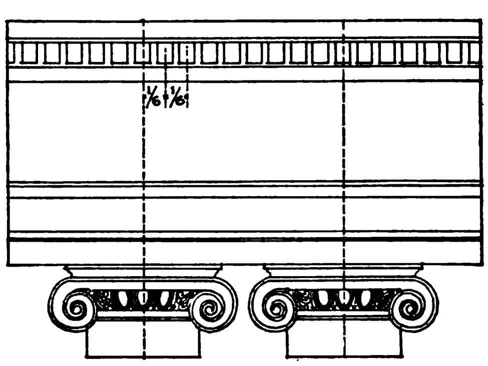


FIG. 61

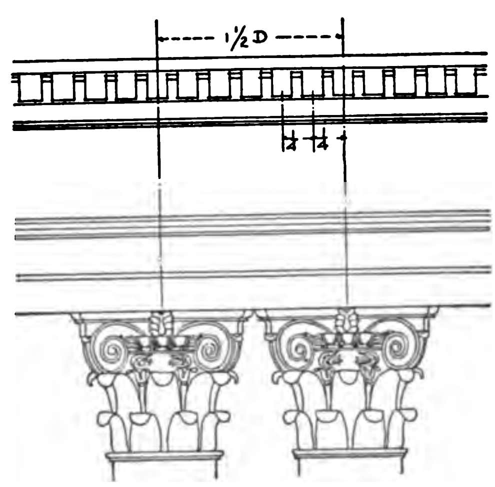


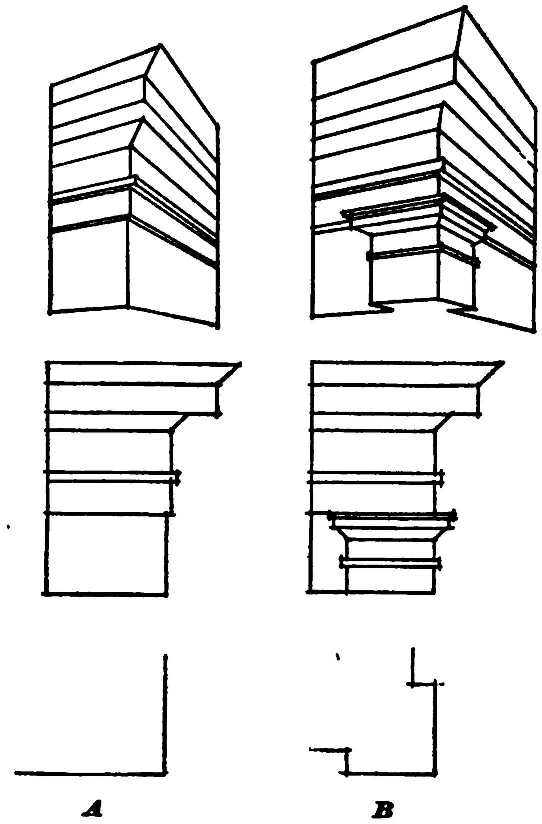
FIG. 62

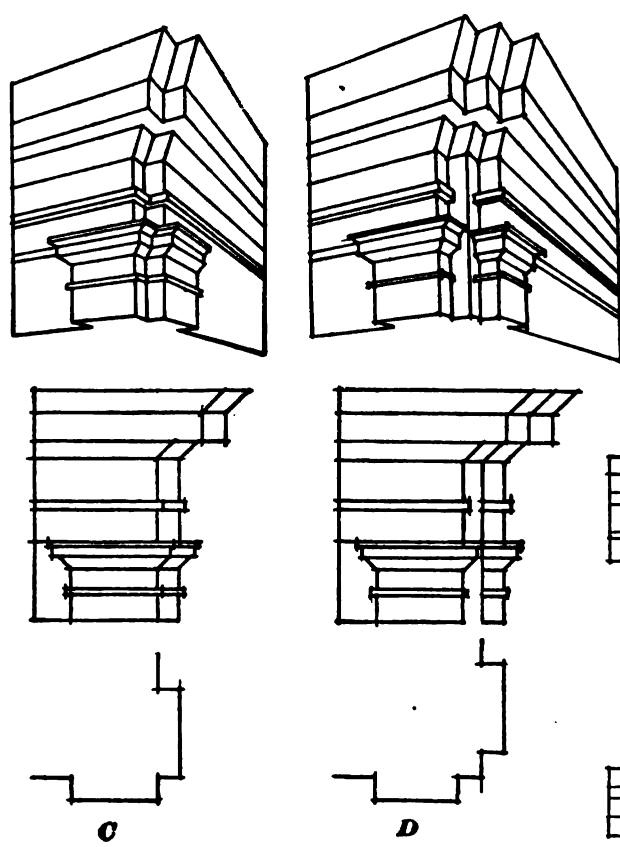
are coupled, it breaks back, so that the frieze and the lower band of the architrave are nearly in the plane of the wall below, there being only just enough projection to give a line of shadow, as shown at *G*.

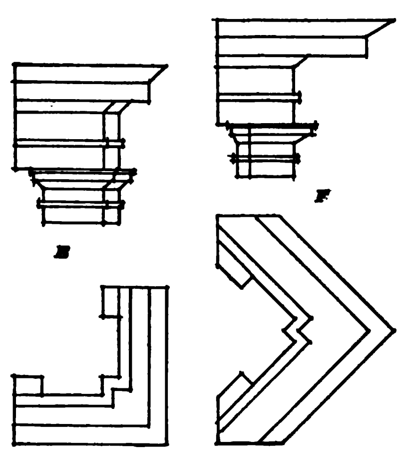
When there is no pilaster, as in Fig. 63 *A*, the treatment of the cornice presents no difficulty. It returns around the corner just as if the corner were occupied by a column. When, also, as in Fig. 63 *B*, the pilaster comes exactly on the corner, forming a square pier, the entablature is treated just as when it rests upon a corner column, except that, since the pier has no diminution (the upper diameter being six-sixths of a diameter, instead of five-sixths), it projects beyond the face of the frieze by one-twelfth of a diameter, whenever the rest of the entablature rests upon columns. But this is undesirable, because the outline of a corner column, though it appears in line with the frieze when seen in elevation, always looks, when seen as usual in perspective, considerably behind it, and a pier projecting in front of it seems obtrusive. It is well, accordingly, to make such a corner pilaster smaller all the way up; viz., eleven-twelfths, or even five-sixths of a diameter. Since a square pier is likely to look too big even in comparison with the other pilasters, and very much larger than a round column, it will well bear this diminution.

The corner Doric pilaster comes under the first triglyph from the corner, and the Corinthian pilaster under the second modillion. The other pilasters are set under any other triglyphs or modillions that may be convenient. But when the pilasters are coupled, the spacing of the triglyphs and modillions over them must be slightly increased, as has just been explained.

Breaking the Tuscan entablature around double and triple corners is easily done, as in Fig. 63, and in the Ionic Order and in Vignola's Composite the dentils present no real difficulty. The Doric triglyphs and mutules and the Corinthian modillions are less easily managed. The arrangements shown in Figs. 64 and 65 offer a fairly satisfactory solution of the problem.







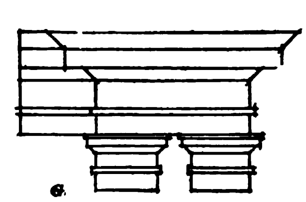


Fig. 63

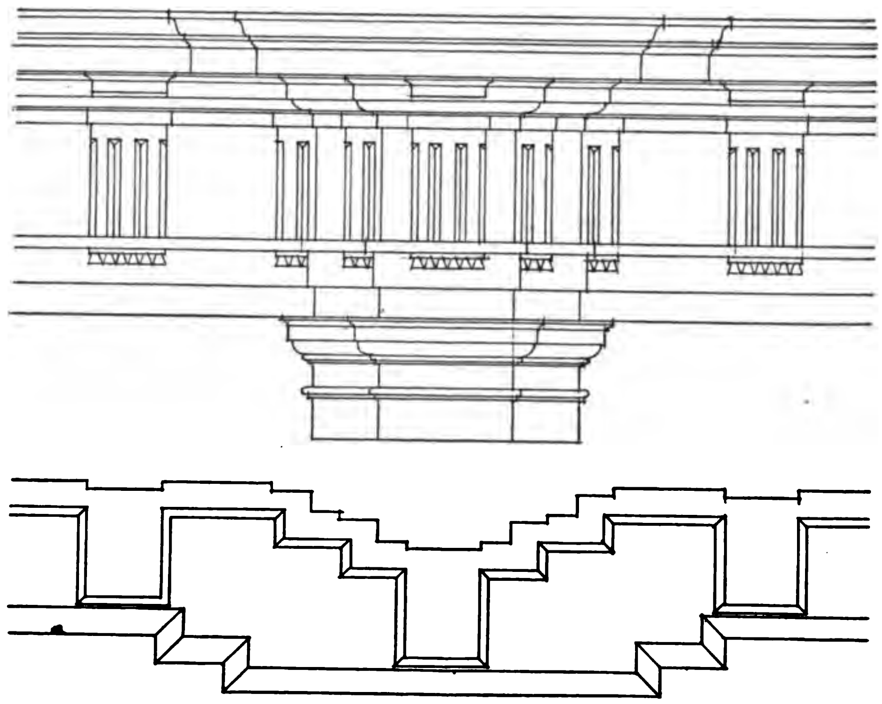


Fig. 64

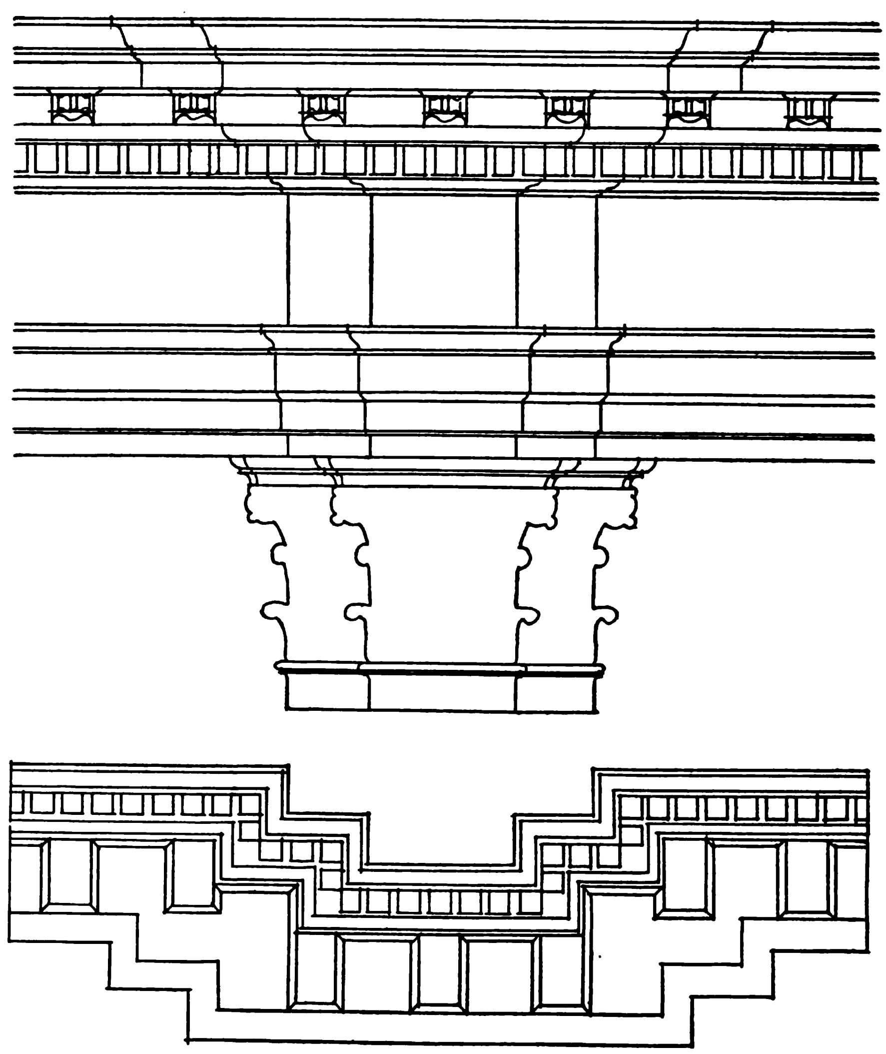


Fig. 65

When the entablature breaks back from the plane of the pilaster to the plane of the wall, the problem resembles that presented by external corners, and admits of analogous solutions.

Internal Corners or Reentering Angles.—Pilasters.—In an internal corner, as in an external one, there are several ways of arranging pilasters. In Fig. 66 *A*, the entablature simply crowns the wall without any other support. In this case, the frieze generally lies nearly in the plane of the wall below. At *B*, there is a single pilaster on each wall; at *C*, a quarter pilaster is added in the corner, giving a pilaster and a quarter pilaster on each wall, the depth of the pilaster being generally a quarter of its width; at *D*, the quarter pilaster is replaced by two half pilasters, giving a pilaster and a half on each wall, but here a larger or smaller fraction may be used. In both *C* and *D*, the whole pilaster is coupled with the fragment in the corner.

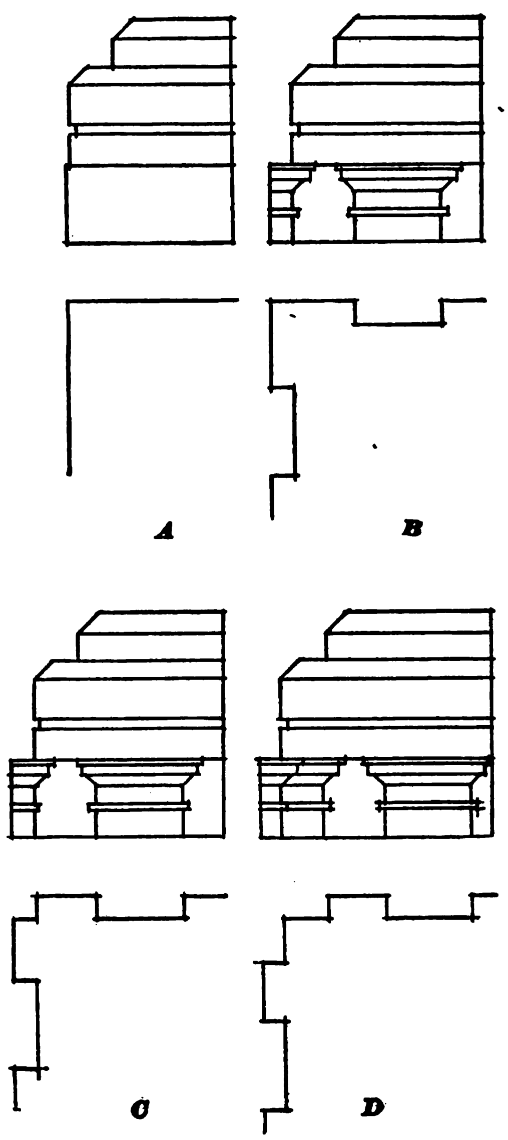


Fig. 66

As in the case of external corners, the entablature does not generally break around the outer pilaster, and unless the pilaster is deeper than usual, the soffit overhangs so little that a sufficient support is afforded by the wall beneath.

In internal corners, as of a room or of a courtyard, care must be taken that the mutules, or modillions, of the two cornices that meet at the reentering angle do not crowd upon or interfere with each other.

The Tuscan Order having none of these details presents no difficulty. Dentils, where they occur (Fig. 67), sometimes have a square interdentil in the corner, flanked by a dentil on each wall, as at *A*, an arrangement that presents, in elevation, the aspect of a double dentil, such as regularly occurs on an external angle. Sometimes a square dentil occupies the corner, as at *B*, and sometimes it is convenient to employ an L-shaped dentil, as at *C*.

Double Corners.—The Mutulary Doric.—Fig. 68 *A* shows a wall surmounted by two entablatures of Vignola's Mutulary Doric Order, meeting on an external angle, and a third entablature forming an internal angle with one of them, so that the corners of the mutules just touch. Since the outer face of each mutule is three-fourths of a diameter distant from the wall behind it, the side of each must be just three-fourths of a diameter from the adjacent wall; and as the mutules are half a diameter wide, the axis of each mutule, and consequently the axis of the triglyph and pilaster beneath it, is just one diameter from the face of the adjacent wall. It follows that, in an internal angle, the edge of a pilaster must be set at least half a diameter from the face of the adjacent frieze, or else the mutules will interfere.

If the mutules are set so far from the adjacent walls that even the little cymatia that crown them do not intersect, then these three dimensions are increased by about one-eighth of a diameter, as in Fig. 68 *B*, and the axis of the pilaster is set about nine-eighths of a diameter from the

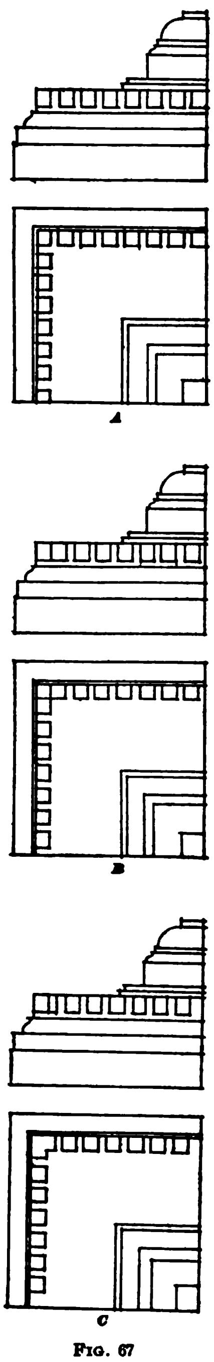


FIG. 67

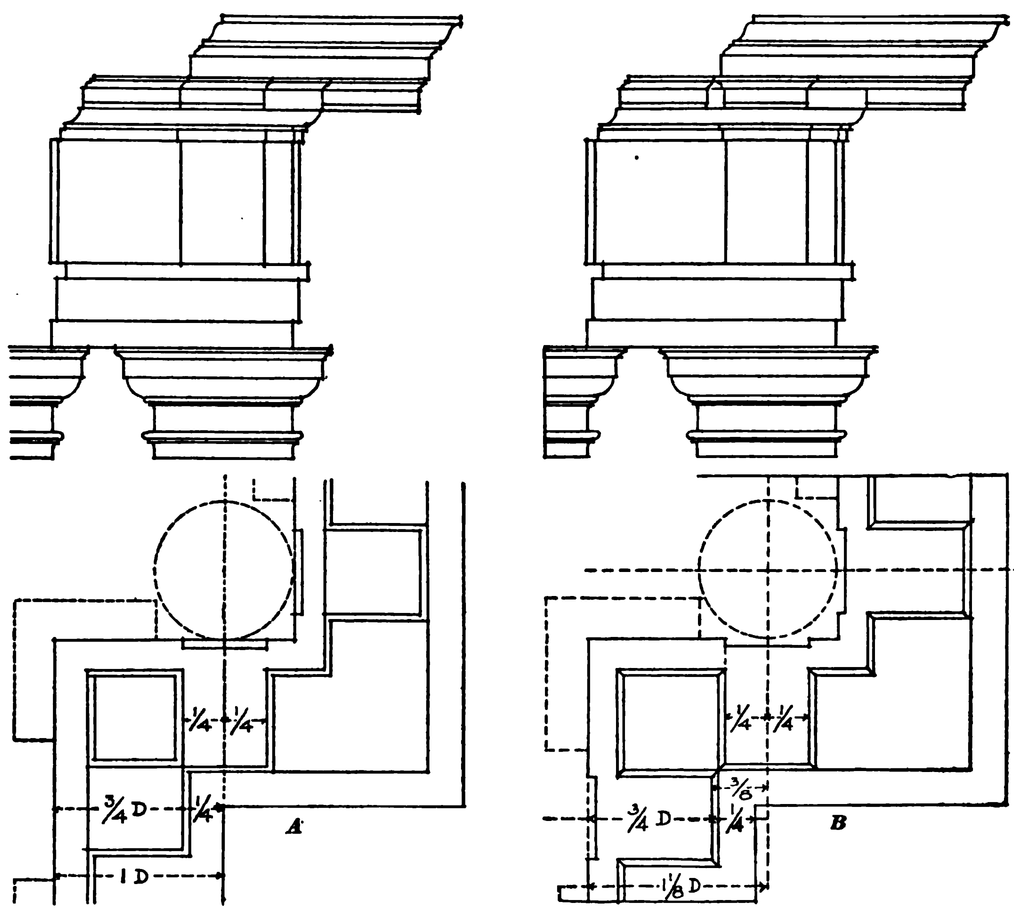


FIG. 68

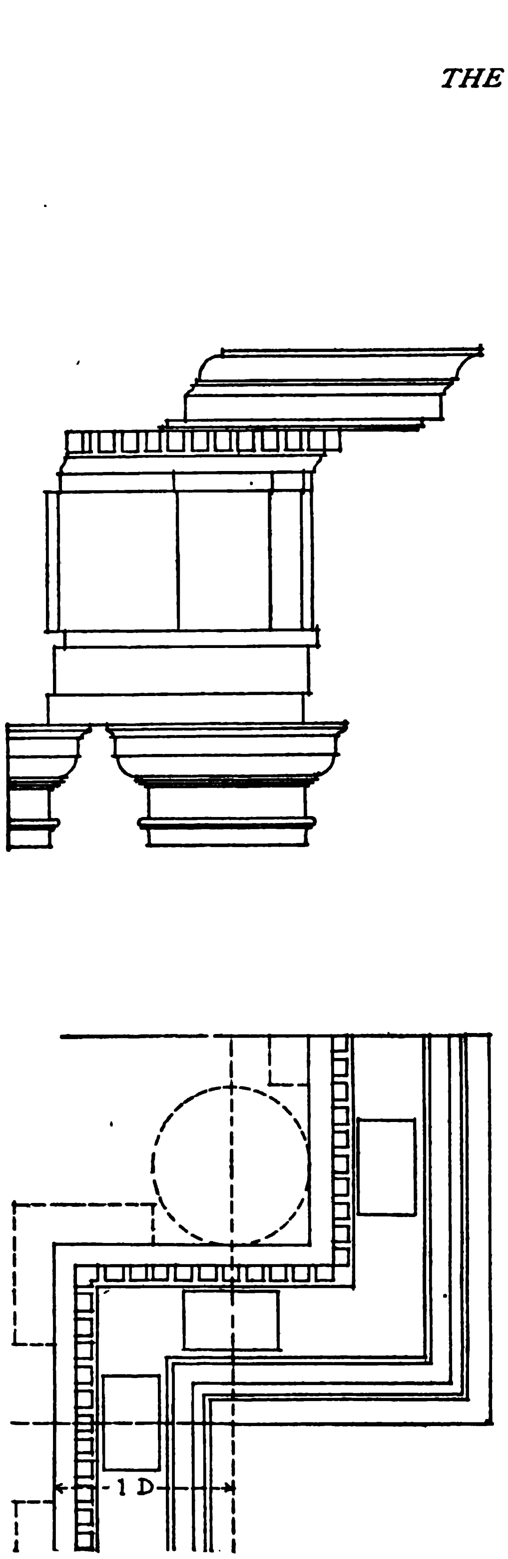


Fig. 69

adjacent wall. In the diagram, the panel in the soffit of the cornice, between the mutules, is square. If the mutules were set farther from the corner, the panel would be L-shaped.

The Denticulated Doric.—When, in an internal angle, two mutules of the Denticulated Doric touch at their corners, the face of one mutule and the side of the other are distant two-thirds of a diameter from the frieze behind it, or from the face of the pilaster that supports it. Since the mutule is half a diameter, or six-twelfths, wide, its axis, as well as the axis of the pilaster, is in this case distant eleven-twelfths of a diameter from the adjacent wall. The edge of the pilaster must then be set at least five-twelfths of a diameter from the adjacent frieze, or else the mutules will interfere (Fig. 69).

The Corinthian Order.—Fig. 70 shows in like manner, *A*, and *B*, external and internal angles formed by the meeting of three Corinthian entablatures. It is necessary that the modillions should be set far enough from the reentering angle not to interfere with each other.

At *A*, the axis of the second modillion from the corner is just one diameter from the face of the adjacent wall, and is accordingly just in line with the edge of the adjacent cornice. The length of the intermediate wall returning at right angles to the others is thus a Diameter and five-twelfths; or, if the pilaster is full width at the top, a Diameter and a half. At *B*, the length of this return is reduced to eight-ninths of a Diameter, and at *C* to two-ninths, or just the width of a modillion. But this pinches the dentils a little and it is better to make the return a little longer than to omit the modillion altogether. At *D*, the break is reduced to one-ninth of a Diameter, or just the width of a dentil. Fig. 68 *A* and *B* shows how walls with pilasters may be substituted for plain walls in the Doric Orders. The same substitution can be made with the Corinthian Order in Fig. 70 *A*.

Columns.—On walls, exterior or interior, columns or three-quarter columns may be used instead of pilasters as decorative features. Half columns are less available, since they have a meager appearance, are awkwardly cut across by horizontal moldings or string-courses, and look smaller than they really are. Three-quarter columns are awkwardly cut by the wall behind them, against which they stand, being more detached from it at the top than at the bottom, and, besides, they have no definite structural significance. They seem too substantial for a merely decorative feature and yet have not, as a full column seems to have, any work to do independently of the wall to which they are attached. Three-quarter columns are, however, at best an unsatisfactory feature and a clumsy one, though from time to time much in vogue. The most satisfactory way is to regard them as the main support of the entablature and the wall above it, and to treat the wall behind them as merely a light screen, only strong enough to carry its own weight and a shallow kind of ornamentation.

This is also the case with full columns, which, as in Mr. Post's new Stock Exchange in New York, and in a shop in Thirty-Fourth Street, next the Hotel Waldorf, may be made to carry the whole weight of the wall above, the wall behind them being merely a screen of iron and glass.

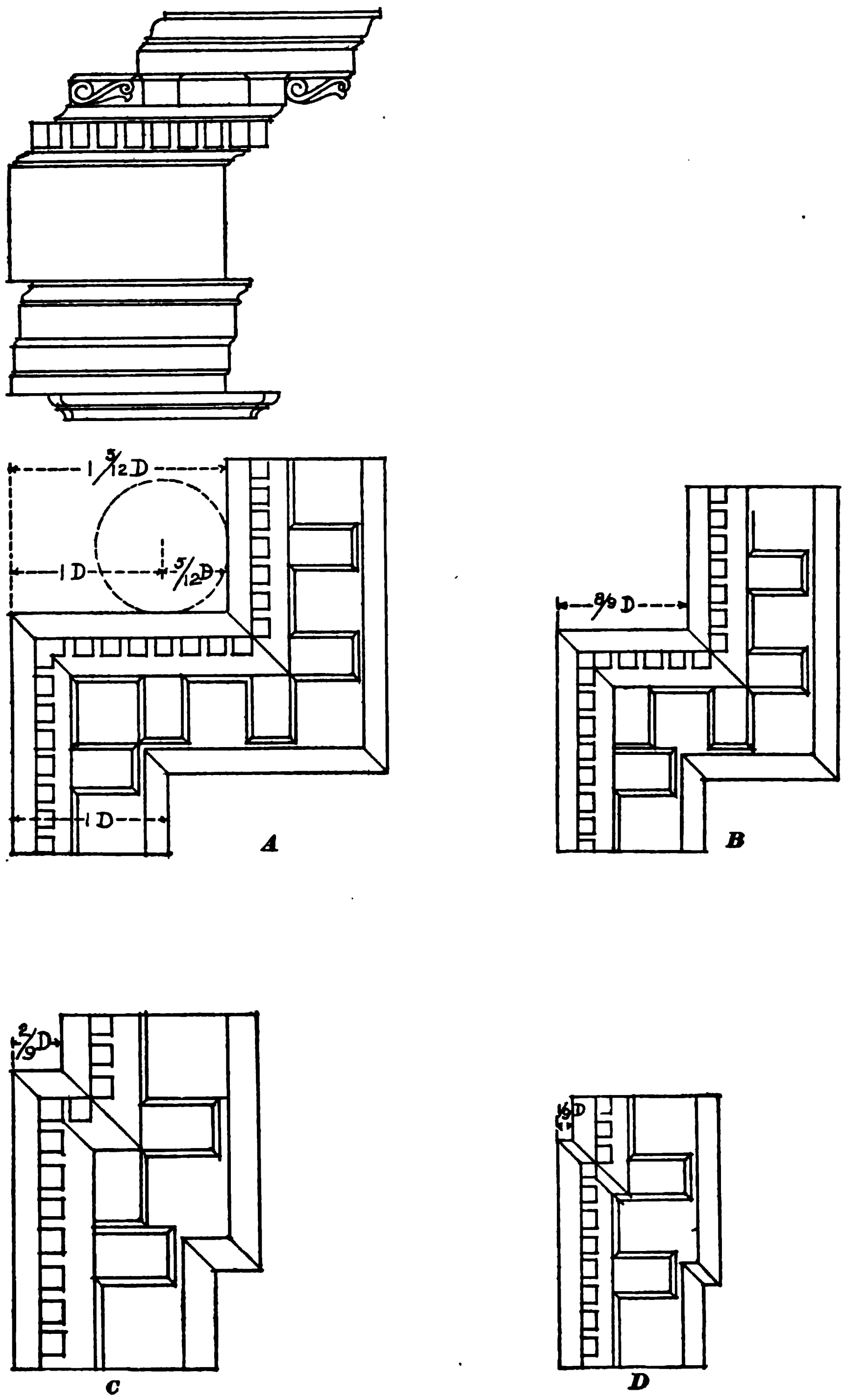
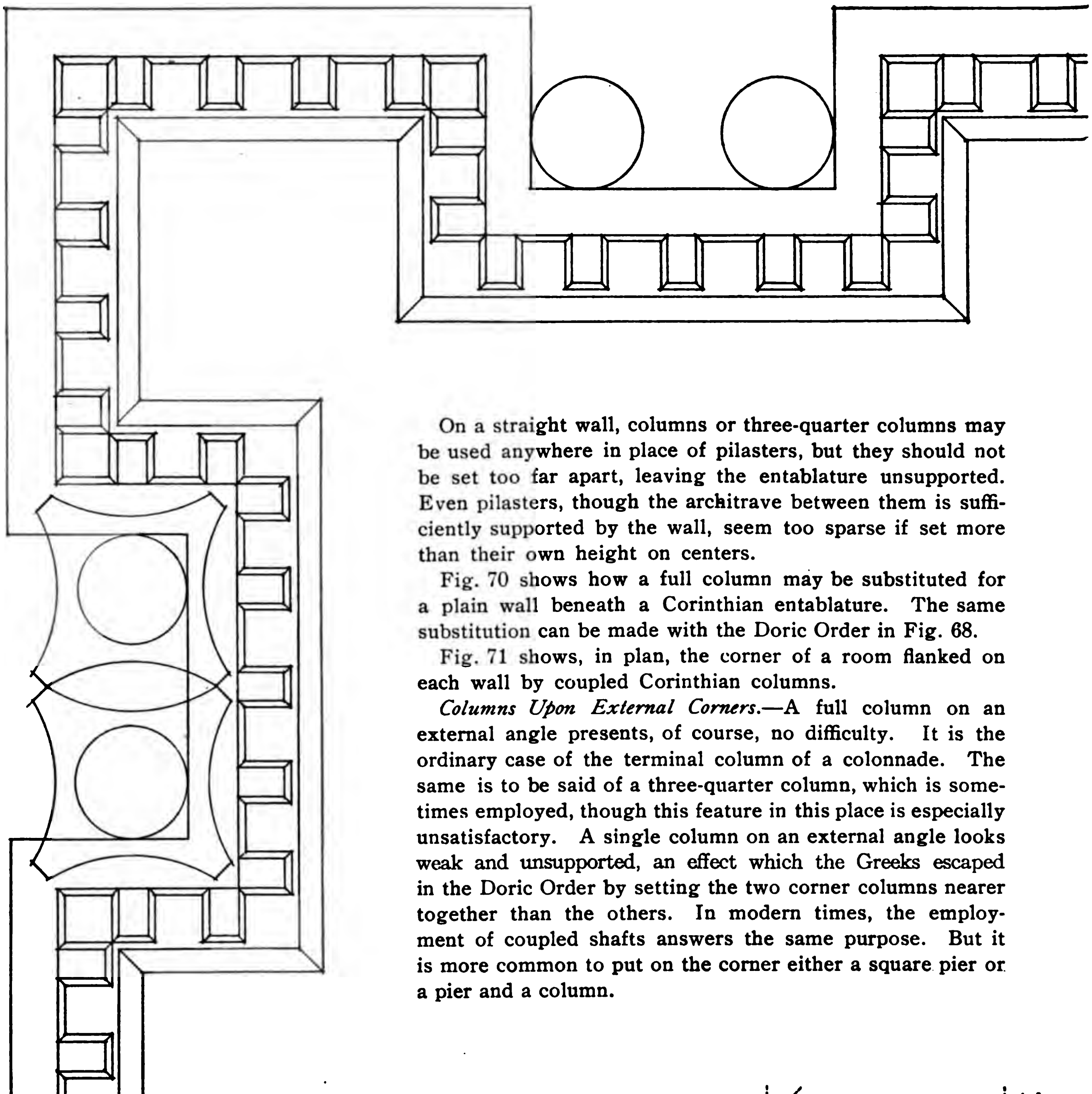


Fig. 70



On a straight wall, columns or three-quarter columns may be used anywhere in place of pilasters, but they should not be set too far apart, leaving the entablature unsupported. Even pilasters, though the architrave between them is sufficiently supported by the wall, seem too sparse if set more than their own height on centers.

Fig. 70 shows how a full column may be substituted for a plain wall beneath a Corinthian entablature. The same substitution can be made with the Doric Order in Fig. 68.

Fig. 71 shows, in plan, the corner of a room flanked on each wall by coupled Corinthian columns.

Columns Upon External Corners.—A full column on an external angle presents, of course, no difficulty. It is the ordinary case of the terminal column of a colonnade. The same is to be said of a three-quarter column, which is sometimes employed, though this feature in this place is especially unsatisfactory. A single column on an external angle looks weak and unsupported, an effect which the Greeks escaped in the Doric Order by setting the two corner columns nearer together than the others. In modern times, the employment of coupled shafts answers the same purpose. But it is more common to put on the corner either a square pier or a pier and a column.

FIG. 71

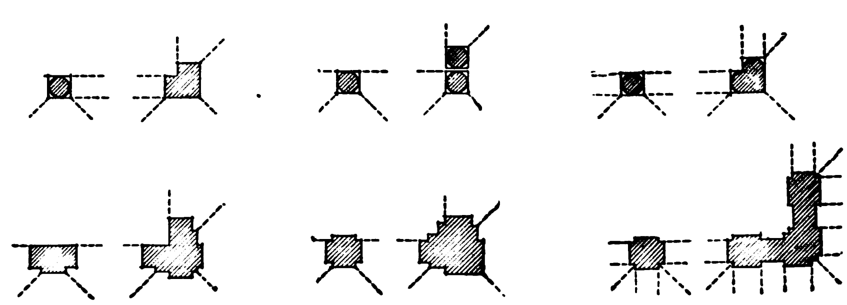


FIG. 72

Columns Upon Internal Corners.—In internal angles, in the same way, a pier, or a pier and a shaft, are commonly used instead of a single column or a group of three columns. The treatment of corners of Arcades is illustrated in Fig. 72 by examples taken from Letaronilly's *Edifices de Rome Moderne.*

Obtuse Angles.—The external angles of octagonal and hexagonal buildings are susceptible of very much the same treatment as square corners. As with the square corners, the result is controlled in the Doric and Corinthian Orders by the arrangement of the mutules and modillions. These must be laid out in such a way that the trapezoidal spaces opposite the angle shall be of as good shape and size as the conditions permit, and the pilasters, if there are any, adjusted accordingly.

Cornices.—The wall and ceiling meet at the cornice, where a series of moldings effects the transition from the vertical to the horizontal surface (Figs. 73, 74, and 75). The simplest way is by means of a large hollow coving, or inverted Scotia, with moldings above and below. If the room is a low one, its apparent height may be increased by putting this more upon the ceiling than on the wall, and vice versa. But it is quite as common to fill the angle with some kind of classical cornice, in which the depth of the corona is frequently diminished or entirely suppressed, and the sinkage on its soffit somewhat exaggerated, so that the soffit is in the same plane with the ceiling, the cymatium appearing as a molding upon it (Fig. 76). When the wall carries pilasters, the cornice has to be supported by a frieze and architrave. In this case, the suppression of the corona or the employment of a coving is hardly admissible.

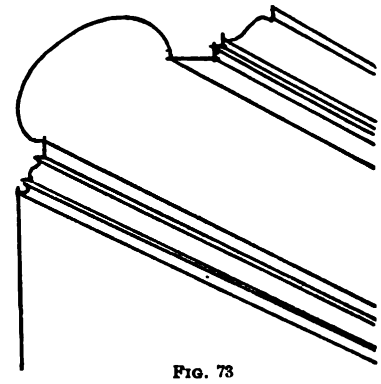


FIG. 73

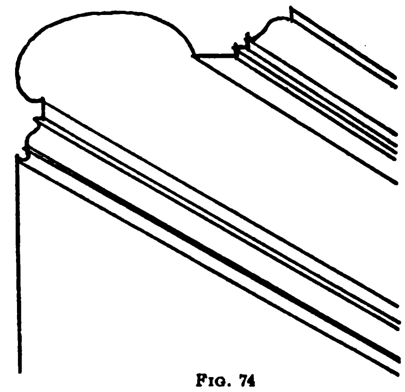


FIG. 74

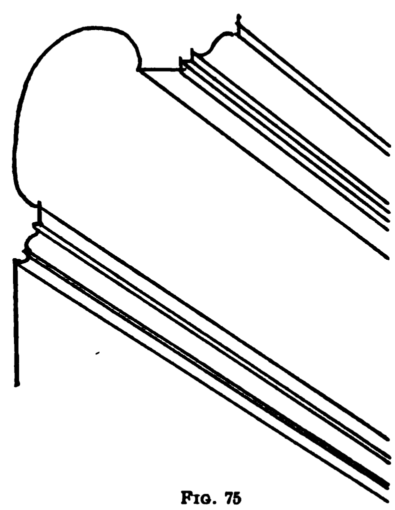


FIG. 75

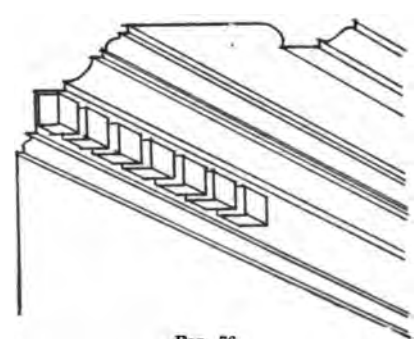


FIG. 76

Ceilings.—Ceilings, whether flat, coved, groined, or cloistered, with or without penetrations, afford an inviting field for decorative treatment, whether by painting or by architectural embellishment, since they are in plain sight, with nothing, in general, to obstruct the view. The only constructive features available for the decoration of ceilings are beams and panels.

Flat Ceilings.—Plate XVI. Flat ceilings occur on the under side of floors built with horizontal beams. These beams are sometimes exposed and decoratively treated with panels or caissons, carved or painted, as shown at *A* and *B*.

Fig. *A* is taken from Reynaud's *Traité d'Architecture.*

Fig. *B* shows a part of the wooden ceiling of the Basilica of Santa Maria Maggiore in Rome. It does not show the beams actually used to support the ceiling, but consists of a series of coffers or caissons made in imitation of two sets of girders equally spaced, and intersecting at right angles.

Fig. *C* exhibits a similar ceiling in the Farnese Palace in Rome. But here the decorative element is predominant, the construction suggested being an unreasonable and almost an impossible one. In ceilings of this sort the wooden panels are generally painted with decorative figures.

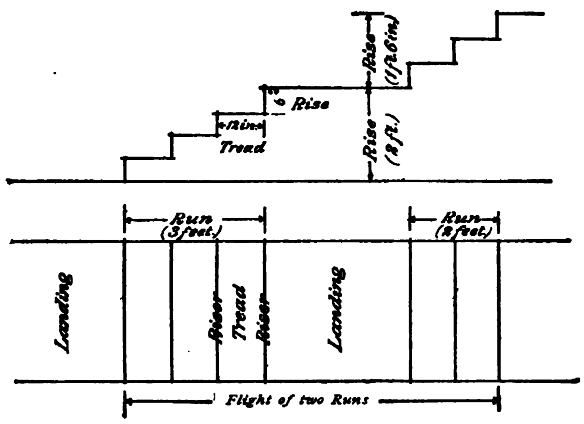


Fig. 77

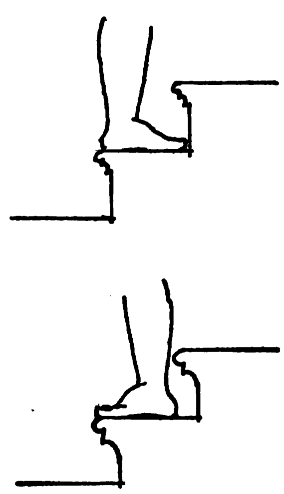


Fig. 78

Fig. *D* shows a part of the ceiling of the Sala Dello Scrutinio in the Ducal Palace in Venice. The panels are filled with pictures painted on canvas, and the moldings that enclose them are carved and gilded like picture frames, and make no pretence of filling any constructive function. This drawing is copied from one of the plates in Zanotto's work upon the Ducal Palace.

Figs. *E* and *F* represent ceilings of plaster and stucco, in which the decorative forms employed are suggested by the nature of those materials. In *E*, which is taken from the building in Bristol called the Red Lodge, these forms consist of a network of intersecting moldings, such as are common in Elizabethan work. Fig. *F* is from a ceiling in Chesterfield House, by Sir Christopher Wren, in the style of Louis XIV.

The plaster surface is often left perfectly smooth, and painted either with ornamental patterns or with pictures. But pictures on a ceiling, though always in plain sight, are difficult to see with comfort, and are apt to look upside down.

The methods used to decorate vaults and domes are similar to those used upon ceilings.

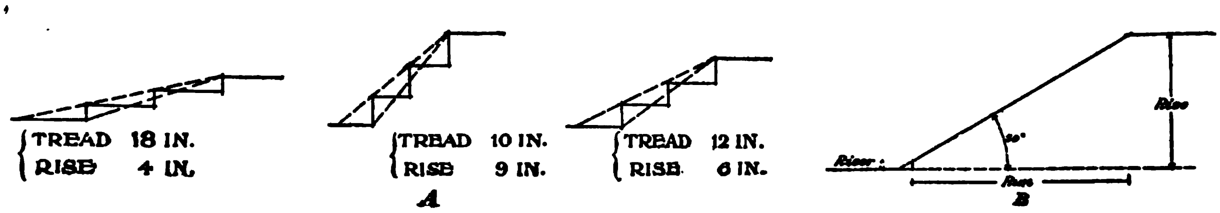


Fig. 79

STEPS AND STAIRCASES

The vertical face of a step is called a *Riser;* the flat part, where the foot rests, the *Tread.* The height of the riser is called the *Rise*, and the width the *Tread.* The total length of the steps, as one goes up, is called the *Run*, and the total height, from level to level, the *Rise.* Rise and tread are thus used in two senses. Rise means either the height of each single step, or the total height of all the steps together; tread means either the top of a step or its width. A resting place half-way up a flight of steps, is called a *Landing*, and the same term is used for the level space at the top of the flight, as well as for that at the bottom (see Fig. 77).

The rise and tread of steps may conveniently be about 6 and 12 inches, respectively. This makes the total Rise about half the Run, and the slope should not be steeper than this. Even 4 inches by 18 inches is not too flat out of doors.

Indoors, stairs may be steeper, and may even be as steep as 7 or 8 inches for the rise and 11 or 10 inches for the tread, without much inconvenience. It follows that the product of the rise and tread, when taken in inches, should be between 70 and 80.

The number of treads is, of course, one less than that of the risers.

Nosings.—The tread is often, especially when narrow, as in steep stairs, made wider than the figured dimensions indicate, overhanging the riser and overlapping the tread beneath. This projection is called a *Nosing* (Fig. 78). It gives more room for the toe in going up stairs, and for the heel in coming down, without diminishing the slope or lengthening the run.

The rise and tread give the true slope of the steps, the Rise and Run giving too steep a slope, as is shown by the dotted lines in Fig. 79 *A*. This is recognized, in sketching the side elevation of a flight of steps, by indicating a single riser and tread at the bottom, as in Fig. 79 *B*. In such preliminary sketches, it is best to make the Run about twice the Rise, as has been said. But a slope of 30 degrees, as in Fig. 79 *B*, is a safe one for such sketches, whether outdoors or indoors. It gives treads and risers of 12 and $6\frac{1}{2}$ inches, or of 11 and 6 inches, very nearly.

When steps come to be accurately figured, the rise of each step has to be expressed in inches and fractions of an inch, since the number of the steps must be a whole number, and the height of each step is the quotient obtained by dividing the total Rise, from landing to landing, by this number. The total Rise being given, say, as 14 feet 6 inches, it is convenient to work out a Table containing the other data, as follows, assuming the rise as 7 or 6 inches and some fraction, and assuming the tread to be exactly $10\frac{1}{2}$, 10, or 11 inches; the Run then comes out as $20\frac{1}{8}$ feet, $18\frac{1}{3}$ feet, or $24\frac{3}{4}$ feet, respectively, as follows:

$$\left.\begin{array}{l}\longrightarrow \\ \\ \\ \longleftarrow\end{array}\left\{\begin{array}{lll}\text{Rise}=14'\,6'' & =\underline{174''}(\ \ \underline{7''}+\tfrac{6}{24}. & 7\tfrac{1}{4}''=\text{rise.}\\ & \left.\begin{array}{l}24\ =\text{No. of risers}\\ 23\ =\text{No. of treads}\end{array}\right\} & \\ \text{Run}=20'\,1\tfrac{1}{2}''=241\tfrac{1}{2}=23\times10\tfrac{1}{2}''. & & 10\tfrac{1}{2}''=\text{tread.}\end{array}\right.\right\}\begin{array}{l}\text{If 7 goes into 174, 24 times and 6 over, 24 will}\\ \text{go into 174, 7 times and 6 over.}\\ \text{This gives 24 risers and 23 treads.}\end{array}$$

If a steeper flight were considered allowable, the table would be as follows:

$$\left.\begin{array}{l}\longrightarrow \\ \\ \\ \longleftarrow\end{array}\left\{\begin{array}{lll}\text{Rise}=14'\,6'' & =\underline{174''}(\ \ \underline{7''}+\tfrac{13}{23}. & 7\tfrac{13}{23}''=\text{rise.}\\ & \left.\begin{array}{l}23\ =\text{No. of risers}\\ 22\ =\text{No. of treads}\end{array}\right\} & \\ \text{Run}=18'\,4'' & =220''=22\times10''. & 10''=\text{tread.}\end{array}\right.\right\}\begin{array}{l}\text{If 7 goes into 174, 23 times and 13 over, 23 will}\\ \text{go into 174, 7 times and 13 over.}\\ \text{This gives 23 risers and 22 treads.}\end{array}$$

If a gentler slope is desired, the table comes out thus:

$$\left.\begin{array}{l}\longrightarrow \\ \\ \\ \longleftarrow\end{array}\left\{\begin{array}{lll}\text{Rise}=14'\,6'' & =\underline{174''}(\ \ \underline{6''}+\tfrac{6}{28}. & 6\tfrac{3}{14}=\text{rise.}\\ & \left.\begin{array}{l}28\ =\text{No. of risers}\\ 27\ =\text{No. of treads}\end{array}\right\} & \\ \text{Run}=24'\,9'' & =297''=27\times11''. & 11''=\text{tread.}\end{array}\right.\right\}\begin{array}{l}\text{If 6 goes into 174, 28 times and 6 over. 28 will}\\ \text{go into 174, 6 times and 6 over.}\\ \text{This gives 28 risers and 27 treads.}\end{array}$$

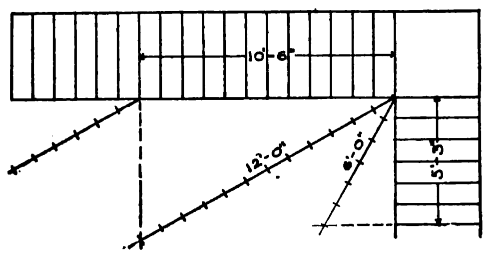


FIG. 80

It thus appears that a slight diminution in the width of the tread makes a good deal of difference in the length of the Run, that is to say, in the space on the ground required for the flight, which is often an important consideration. The same result is reached by slightly increasing the height of the risers, and thus diminishing their number and the number of treads.

If the width of the tread, in inches, is known, or assumed, it is plain that twelve treads will occupy as many feet as there are inches to the tread. This makes it easy to lay out, in plan, at any given scale, a run of twelve treads, or, by halving or doubling this dimension, a run of six treads, or of twenty-four. The position of the risers and the width of the treads may then be laid off by using a scale of twelve, twenty-four, or six, equal parts. Fig. 80 shows how two runs, one of eighteen treads and one of six, can be thus laid off by the aid of a rule showing 12 feet at the required scale, the treads being 10½ inches wide. This is useful, in first sketches, to find out how much room on the ground a stairway will take up.

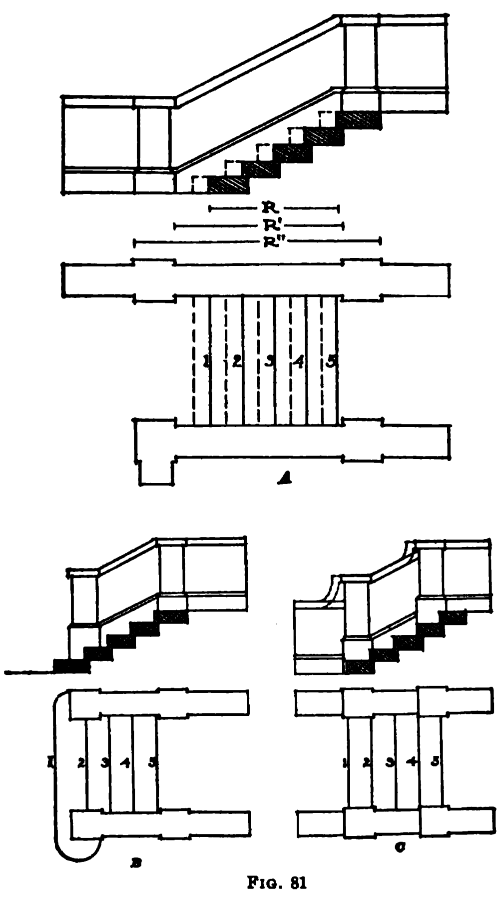


FIG. 81

Fig. 81 *A*, *B*, and *C* shows a plan and section of a flight of five steps, in one run, with a sloping parapet on each side. At the top and bottom of the run are pedestals or posts. These posts are of the same height as the parapet, and have similar caps and bases.

At *A*, the caps and bases are shown as continuous, the sloping members being at the same height from the edge of the step that the horizontal members are from the ground, and making a slight angle at the top and bottom, so that the moldings may miter. As a result of this, the run of the rail and base, as shown at R', is longer than the run of the steps, as seen at R, by the width of one tread and the space required for these angles. The space required for the parapet and the two posts together is greater still, as shown at R'', by twice the width of a post. As this is rather an awkward arrangement, making the lower landing very long, especially when the lower rail turns at right angles, as in the figure, it is usual to set the steps farther out, as shown by the dotted lines. This increases the length of the upper landing, and diminishes that of the lower one, by half the width of a step; but it also makes the height of the sloping rail, measured from the edge of the step, less than that of a horizontal rail, by half the height of a step. Either method may be adopted when there are no posts and the rail is continuous.

But when the parapet is not continued beyond the lower post, the post is often set up on the first or second steps, which are in that case generally made wider and broader, to serve as a base to it, and sometimes curled around it, in what is called a *Curtail*, as in Fig. 81 *B*.

It is customary, in order to save room, not only to set back the lower post upon the lower step, but also to set forwards the upper post, thus bringing the two posts still

nearer together, as in Fig. 81 *C*. It is not then necessary to lower the height of the sloping rail, but the plinths are lengthened and the bases run into them. The rails then either run into the dies of the pedestals, as in the figure, or rise with a sharp curve, called a *Ramp*, to the level of their caps, as shown by the dotted lines.

The sloping parapet sometimes rests upon a sloping base, called a *String*, as in the upper run shown in Fig. 83 *B*. Sometimes, as in Fig. 83 *A* and *C*, it rests upon the steps, the ends of which show beyond it. A *Balustrade*, as in Plate XVII, is often used in place of a parapet, the balustrade resting sometimes upon a continuous string, as in the Plate, sometimes on the steps themselves. When two balusters come upon the same steps, the upper one is longer than the lower one by half the height of the riser. In stone balusters this difference is generally gained by making the plinth higher. But in wooden balusters the additional height is often put into the ***sleeve.***

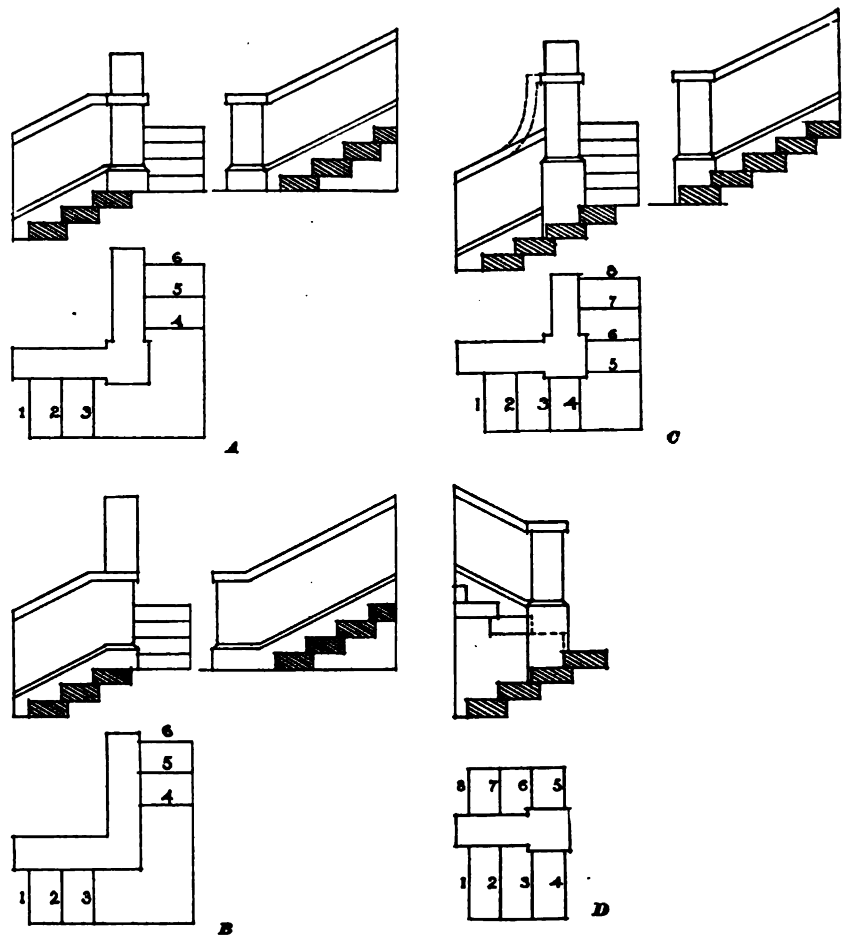


FIG. 82

Flights of Two and of Three Runs. Fig. 82 *A*, *B*, and *C* shows flights of steps in two runs, at right angles to one another. If the rails are continuous, as at *A*, the landing between the runs is **L**-shaped, since it is both at the top of the first run and at the bottom of the second. The same thing happens when there is no post, as at *B*.

If the post is moved so as to give a square landing, the rails are discontinuous and the post is twice lengthened, once because it is at the top of the lower run and

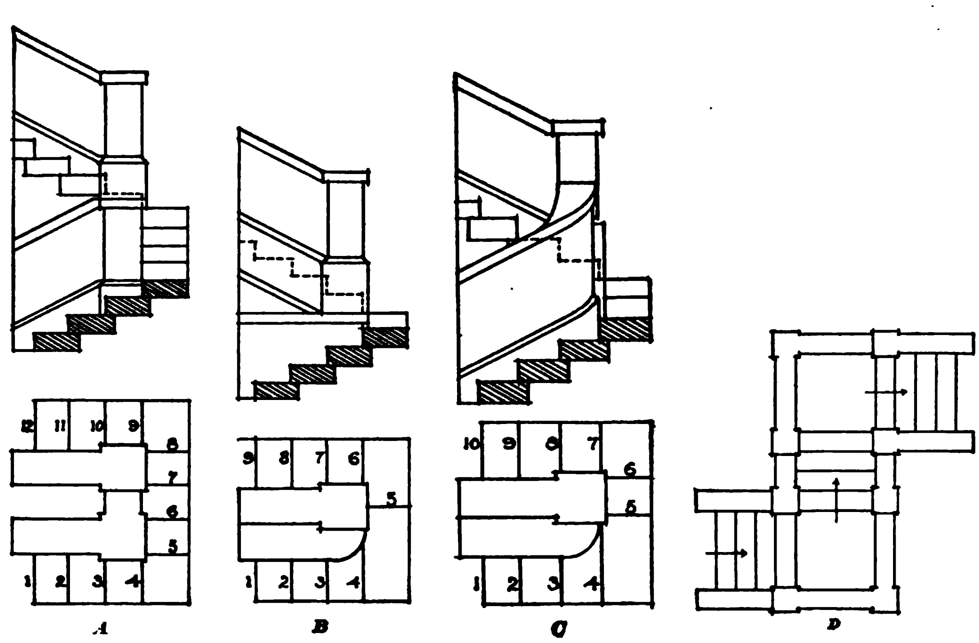


FIG. 83

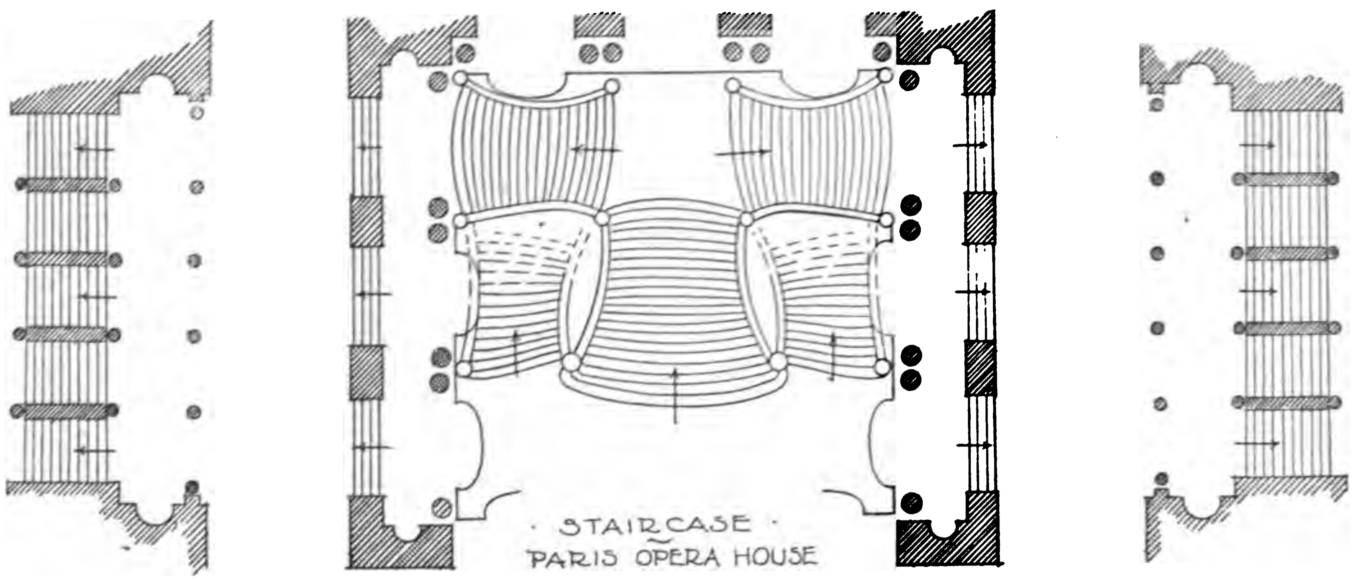
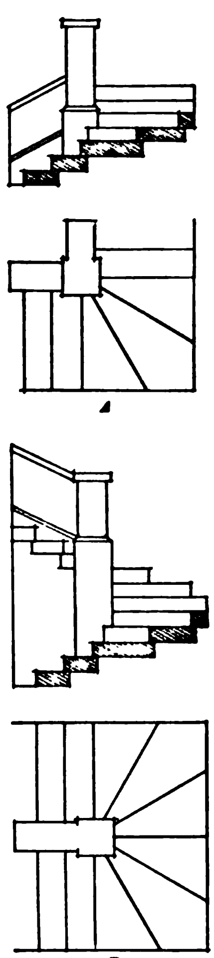


FIG. 84



A

B

FIG. 85

once because it is at the bottom of the upper one, as appears at *C*. If the second run is parallel to the first one, as in Fig. 82 *D*, the same thing happens; but in this case the rail of the lower run is generally omitted, as in the figure.

When, in a flight of three runs, the second run consists of three or four steps, as in Fig. 83 *A*, there is room for two posts, and no new conditions are encountered; but when the second run consists of only one or two steps, the rail of the lower run is sometimes omitted and carried along a sort of horizontal shelf, as at Fig. 83 *B*. It is then best to have only one post, as in these figures. When the lower rail is not omitted, it is sometimes turned sidewise into the die of the post, as in Fig. 83 *C*. It is awkward to give this twist to a ramp.

In a flight of three runs, the second run should either be so short that, as in these examples, there is no open space between the two runs, or so long that this space is a wide one. A narrow pocket is to be avoided.

The third run may either reverse the direction of the first one, as in the previous figures, or continue it, as in Fig. 83 *D*.

In all these cases, the right lines of the steps may be replaced by curved lines, as in the Opera House at Paris (Fig. 84), the axis of the runs being still rectilinear.

Winders.—It is a saving of room to replace the square landing beween two runs by triangular steps, as in Fig. 85 *A*. Three is the best number, for if there are only two the treads are somewhat broader than those in the straight runs; and if there are more than three, they are narrower; in either case the change is undesirable. Besides, it is so much the custom to have three winders, if any, that any other number is disconcerting. The extra steps, of course, make the plinth of the post higher than it would otherwise be, by the height of two risers, as in the figure.

When the second run returns upon the first, as in Fig. 85 *B*, bringing six winders together, the length of the plinth is increased by the height of the rive risers.

Circular Steps.—The axis of the runs is sometimes itself a curved line, being laid out on a circular or elliptic arc, as in Plate XVII, *A* and *B*. If the radius of the inner curve is about half that of the outer curve, there will not be too much difference in the width of the treads at the two ends, and the slope will at no part be much too steep or too flat. The rise and tread are then laid off upon a *Line of Tread*, at a

convenient distance from the inner rail, generally about 18 inches. This distance may, however, be greater when the inner radius is large.

A circular flight of steps with no wall under the inner string and rail is called a *Geometrical Staircase*.

Circular steps of all these kinds are used outdoors, both as approaches to buildings and as architectural features in gardens.

In circular steps, the lines of the rails and strings are all spirals, which in elevation are projected as *Sine Curves*. These are curves of contrary flexure which, at their points of least slope, where they are parallel to the plane of projection, show the true inclination of the rails and strings (Plate XVII). The slope is, of course, much steeper for the inner rail than for the outer one. The obtuse angle at the top of the flight, where the sloping rail joins the horizontal one, is here, as elsewhere, often replaced by a ramp.

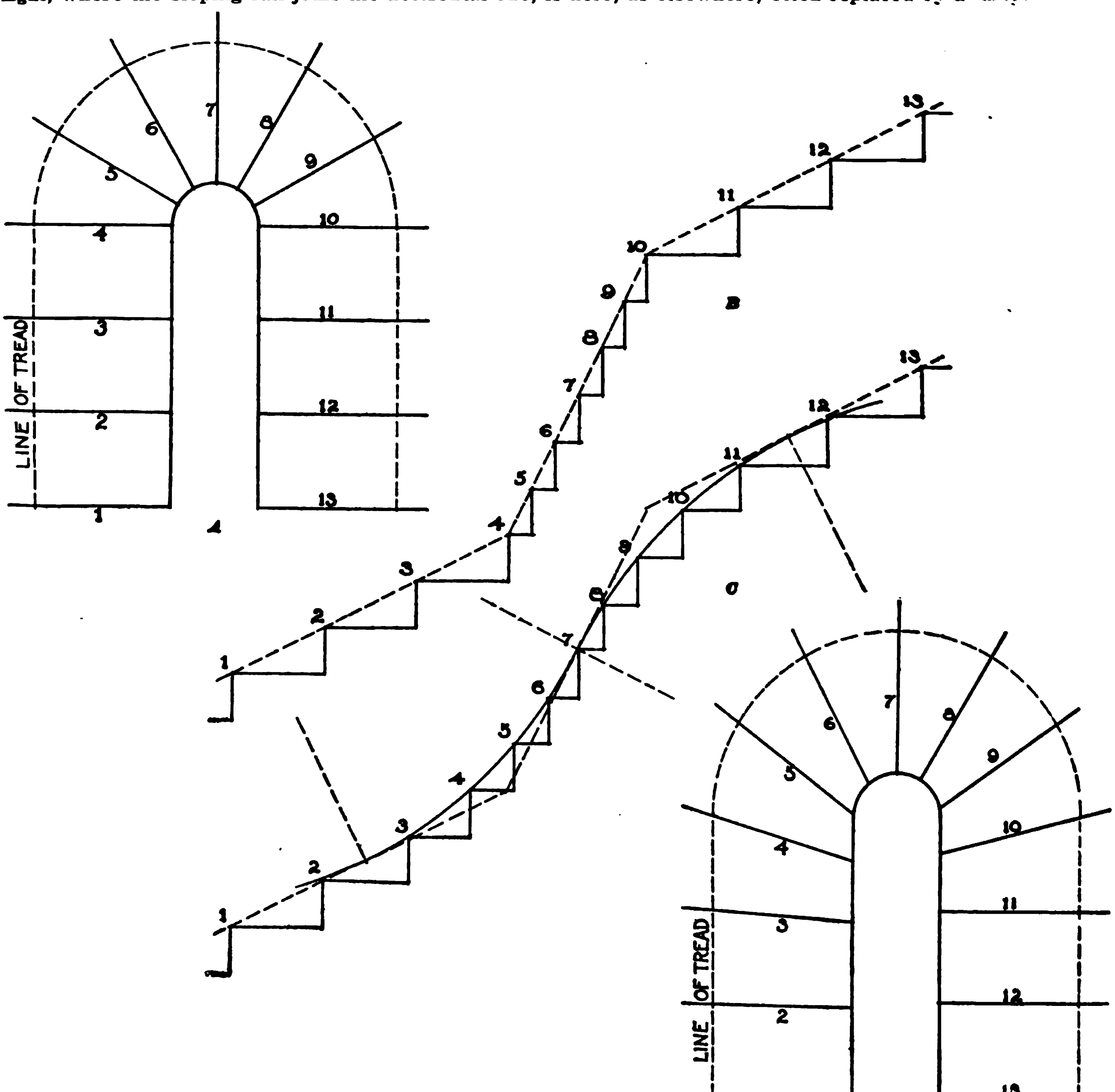


FIG. 86

Balancing.—When, as in Fig. 86 A, a flight of steps consists of a circular run between two straight ones, although there is no change of slope upon the line of tread, there is at the outer end of the steps a sudden change to a flatter slope, and at the inner end to a steeper one, as appears at B, where the inner string, with the ends of the risers and treads, is developed. The hand rail over it also makes two obtuse angles. It is practicable to avoid this awkwardness by what is called *Balancing*, or *Dancing*. For the broken line at B is substituted a curve of contrary flexure, as at C, consisting of two arcs of circles tangent to one another and to the broken line. The risers and treads at the inner ends of the steps are then redrawn to meet this curve. The width of the treads, instead of changing suddenly, now changes gradually from their greatest width to their least, and then gradually back again. The widths of the treads at their inner ends, thus ascertained, are then laid off upon the plan, as at D; and from the new positions of the ends of the risers, the risers themselves are drawn, as shown, through these points and the points originally taken upon the line of tread. The plan at A gives the broken line at B; the curved line at C gives, inversely, the plan at D.

Elliptic Steps.—Since concentric ellipses, though they may be equidistant along their axes, are somewhat nearer together at their haunches, it is not desirable to have true ellipses at both ends of the steps. If the inner curve is a semi-ellipse, the outer curve should be a semi-oval drawn equidistant from it. But it is more common, and easier, to substitute, in both cases, a three- or four-centered curve, as in Fig. 87 A, B, and C.

Equal distances being laid off upon a line of tread, the radiating lines of the risers may either be drawn to the center, as at A, or taken at right angles to the two curves, as at B. The first method gives excessively acute angles at the inner end of the steps; the other gives very wide treads near the ends of the ellipse, and a very gradual slope at their outer ends. But if these come at the top and bottom of the flight, as they generally do, this is no great disadvantage. It is customary to have wide steps at least at the bottom of a flight. But it is more usual to disregard the line of tread, and to divide both curves into an equal number of parts, drawing the lines of the risers between the points thus found, as at C.

Fig. 88 A shows how such a semi-oval can be drawn from three centers. (1) Lay off from the center O the semi-axes OA and OB, and then from one extremity of the major axis lay off the length of the semi-minor axis, to the point D ($AD = OB$). From the point D thus obtained, draw a line at 45 degrees until it touches the minor axis, and from the same point lay off half the length of this diagonal line backwards along the major axis, to the point C'. This point is one of the desired centers. (2) A second diagonal line, drawn at right angles to the first one through the point C', will cut the minor axis at the point C'', which is another of the desired centers. The third one, C''', will be symmetrical with the first on the major axis.

This method does not work well when, as in the smaller ovals shown in Fig. 87, the minor axis is less than two-thirds of the major axis.

Fig. 88 B shows how such a semi-oval can be drawn from five centers. (1) Taking the point O as the center of the required oval, draw the parallelogram $OAHB$, OA and BH being the length of the semi-major axis, and OB and AH of the semi-minor axis. (2) Draw AB and $HC'C''$ perpendicular to it. C' and C'', and C''' symmetrical with C' are three of the required centers. (3) Taking OD equal to OB, describe upon AD as a diameter the semicircle $AEGD$, E being at the summit of the arc, and find F upon the vertical radius. (4) Take OP equal to EF. (5) Taking C'' as a center, draw an arc with a radius $C''P$, and cut it by two arcs drawn with the points A and A' as centers and GO as a radius. The points of intersection C^{iv} and C^{v} are the two other required centers. The line of the oval coincides with that of the ellipse, as shown by the dotted line, much better in this figure than in the other.

NOTE.—It is easy to prove by a little simple algebra that, in figure A the sum of the lines AC' and $C'C''$ equals the sum of BO and $C'O$. A corresponding procedure for figure B would be more complicated. It is not necessary to introduce either demonstration here.

Symmetrical Steps.—Two flights of steps, whether of one, two, or three runs, may be set back to back or face to face, as is shown in Figs. 89, 90, and 91. The middle runs, upon which the others meet, are naturally wider than the others. Fig. 89 shows flights of one run. They are face to face at A, and back to back at B.

When, in symmetrical flights of two runs, the two runs are at right angles with one another, the lower runs may either be between the upper ones, as in Fig. 90 A, or the upper runs between the lower ones, as in Fig. 90 B. In either case, all the steps rest upon walls, which themselves rest upon the ground. But when the upper run is parallel to the lower one, as in Fig. 90 C and D, it is better to have the lower run in the middle, as at C; otherwise, the upper run is either unsupported, as at D, or rests upon the walls that encumber the ground below.

This is only partly avoided by carrying the run upon arches, as in Fig. 96. When the two flights are parallel to one another they may be either side by side, as at C and D; face to face, as at E, or back to back as at F.

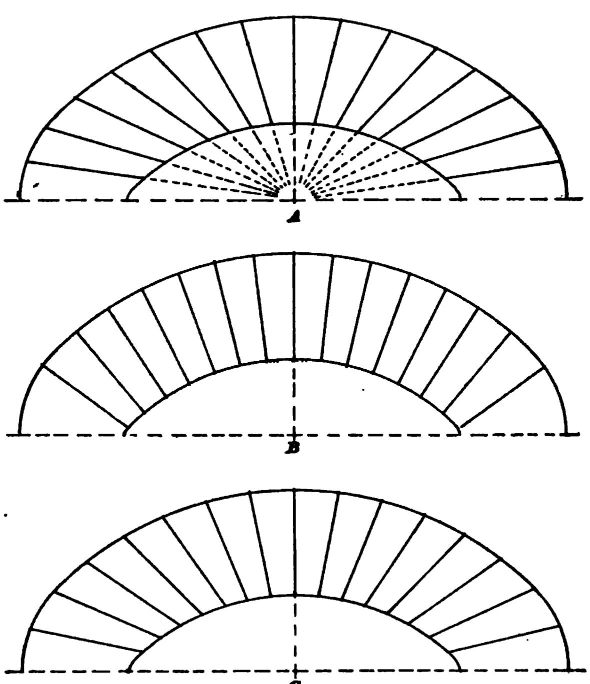


Fig. 87

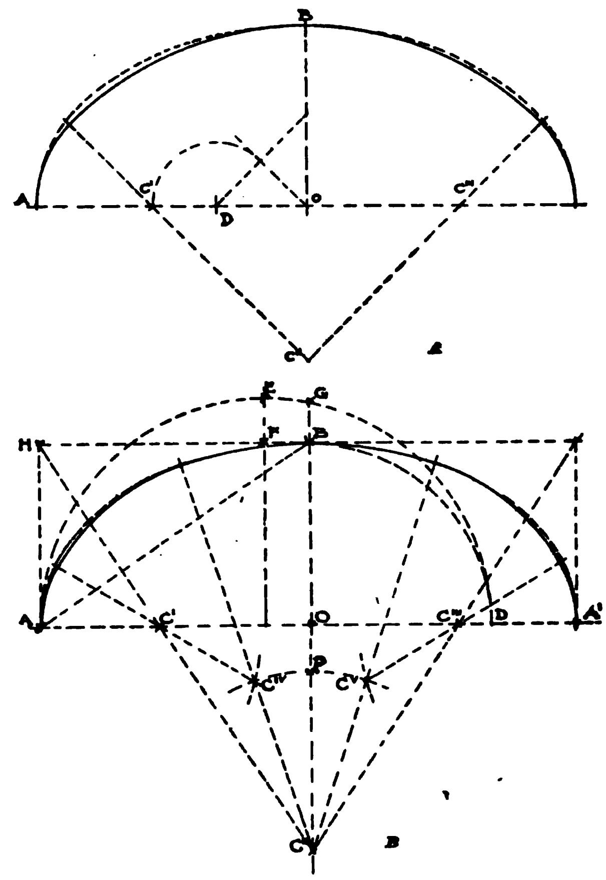


Fig. 88

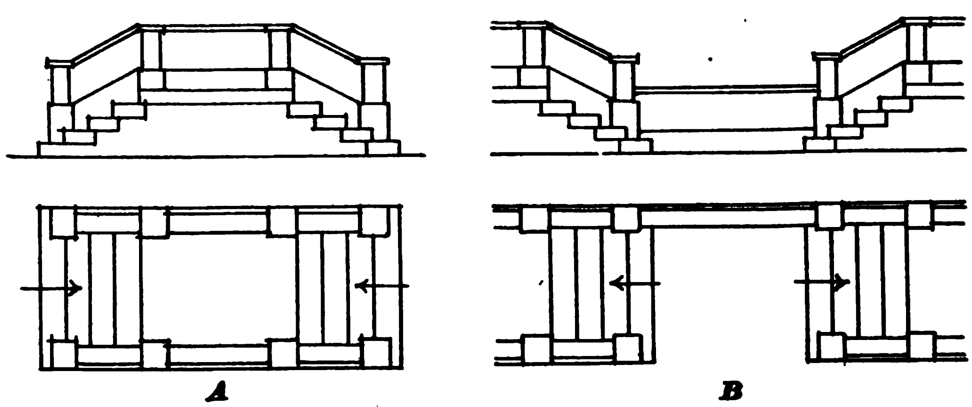


Fig. 89

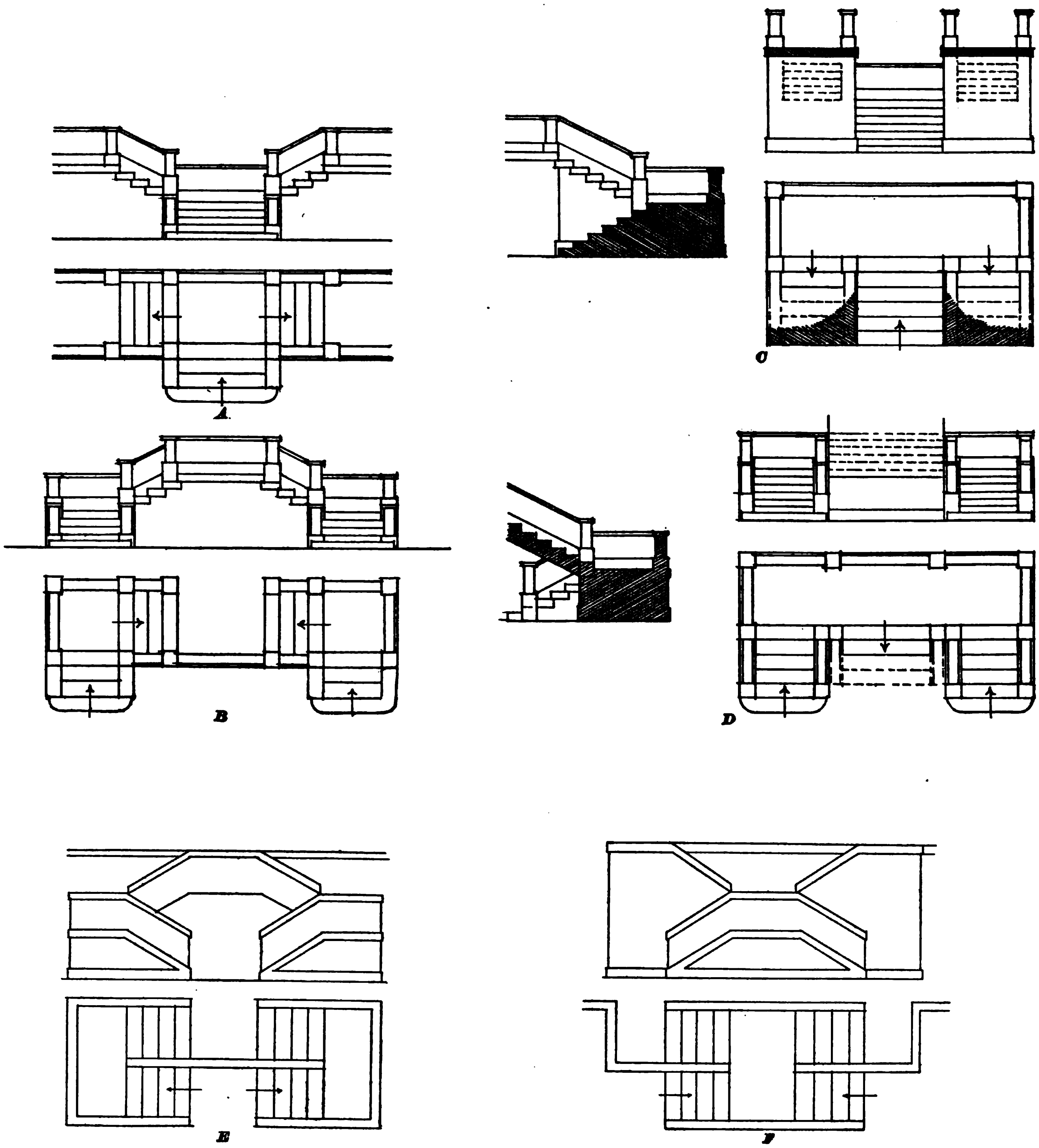


FIG. 90

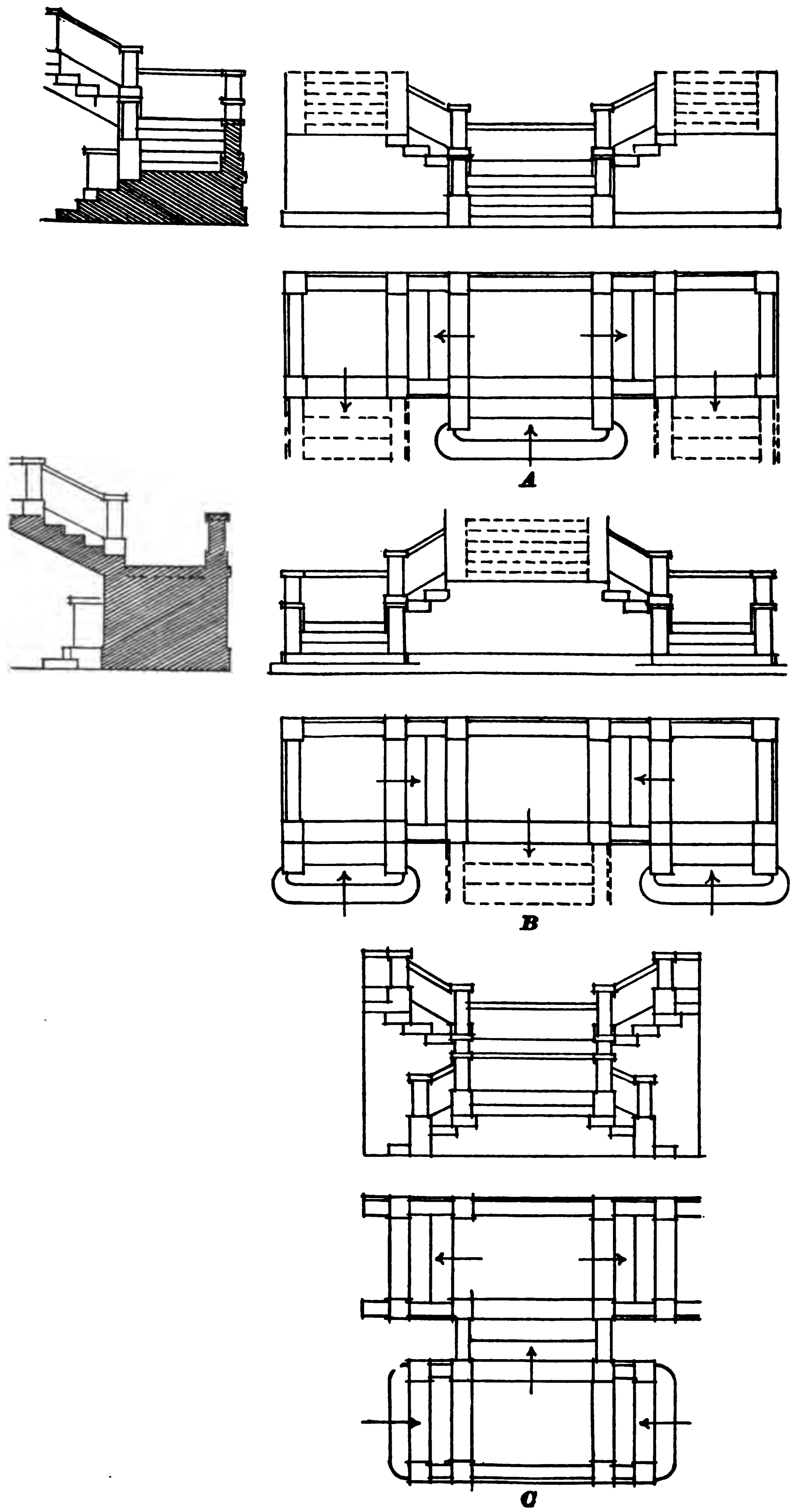


Fig. 91

The same is true of symmetrical steps of three runs, as shown in Fig. 91 *A* and *B*. At *C* the two flights are side by side, having the middle run in common.

But when, in flights of two runs, as in Fig. 92 *A* and *B*, the upper run has the same direction as the lower run, very elegant arrangements result, whether the lower runs are united and set in the middle, or are divided and set on either side. The same may happen with steps of three runs, Fig. 93 *A* and *B*. In either case, a little lawn or garden plot may be laid out on a level with the second landing, as is shown in the right-hand side of the figures.

Cruciform Steps.—Another picturesque and sometimes convenient scheme is that of the Cruciform plan, as shown in Fig. 94 *A*, *B*, *C*, and *D*. At *A*, a single lower run leads to a square landing from which rise three

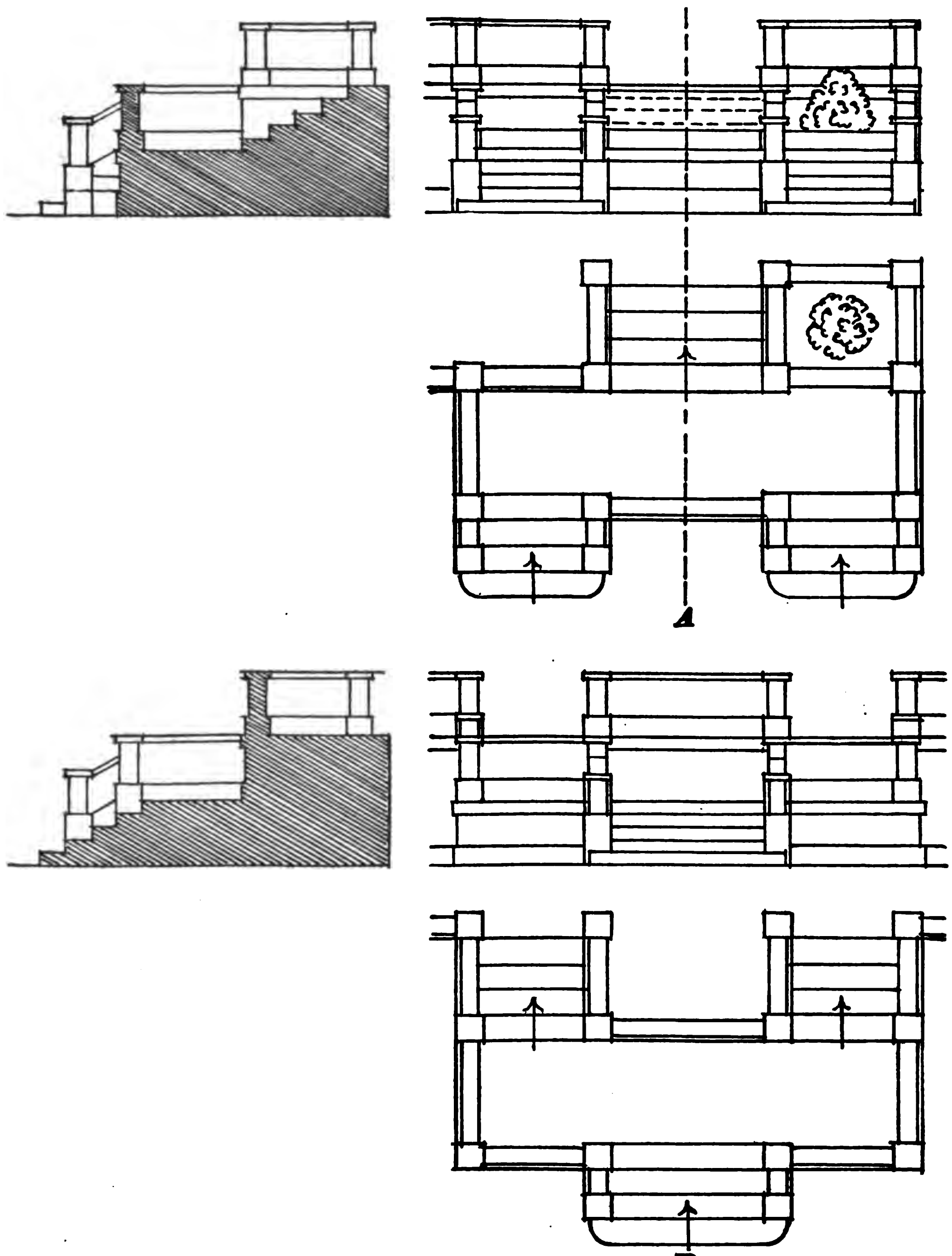


FIG. 92

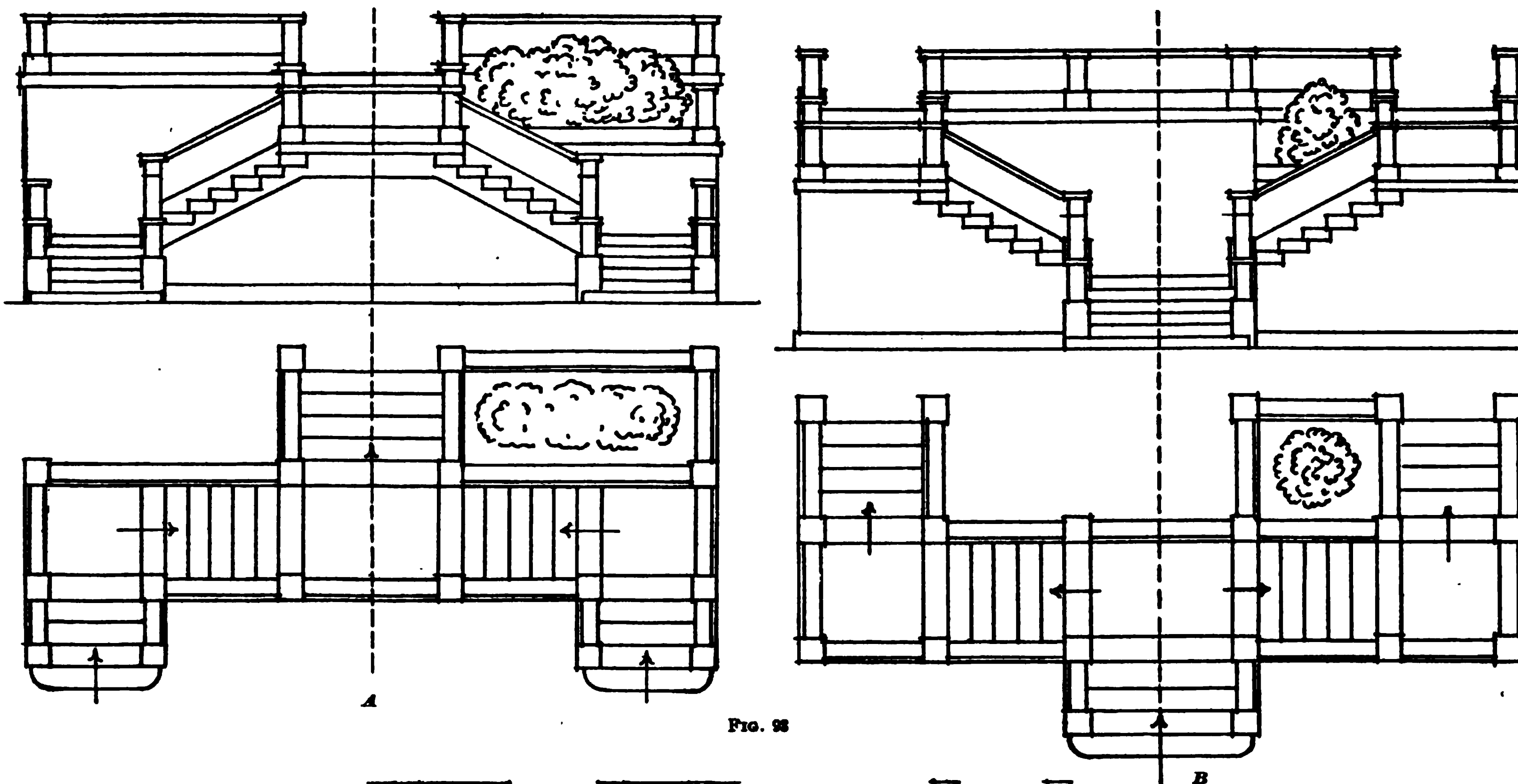


Fig. 93

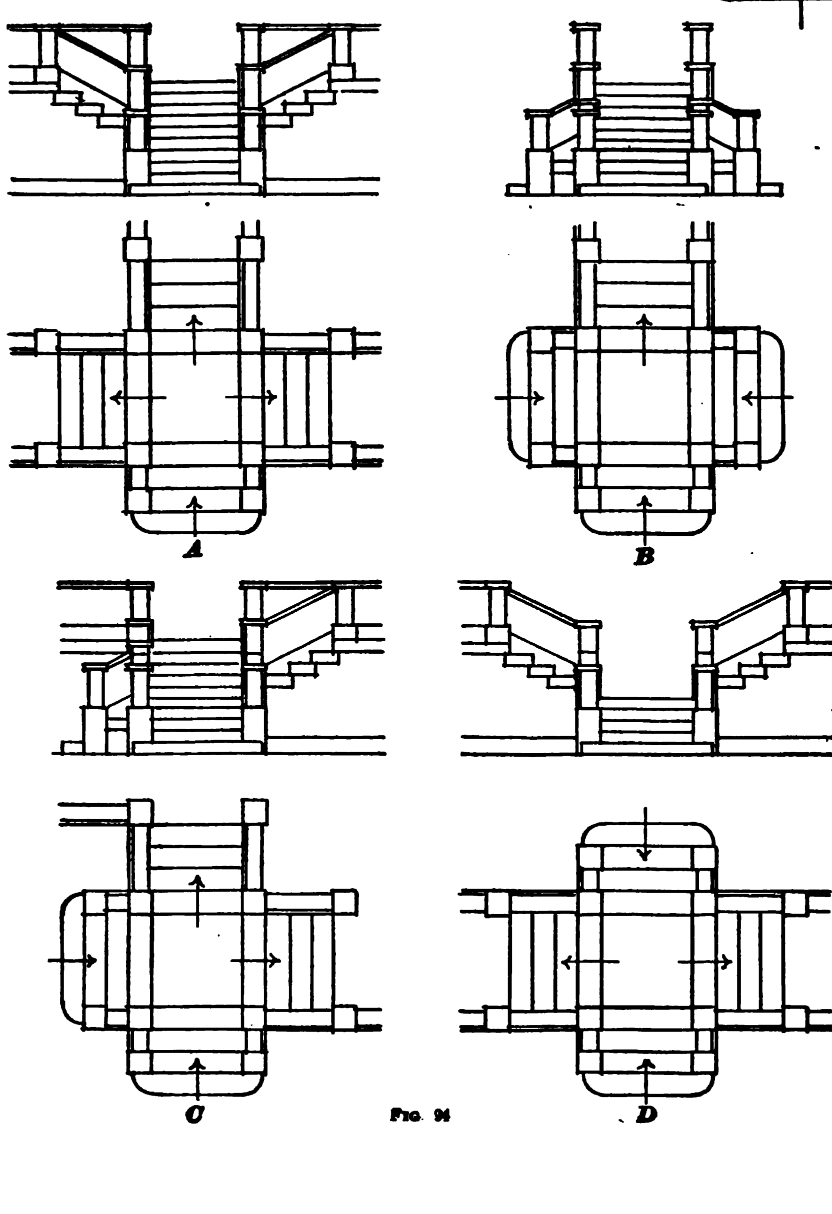
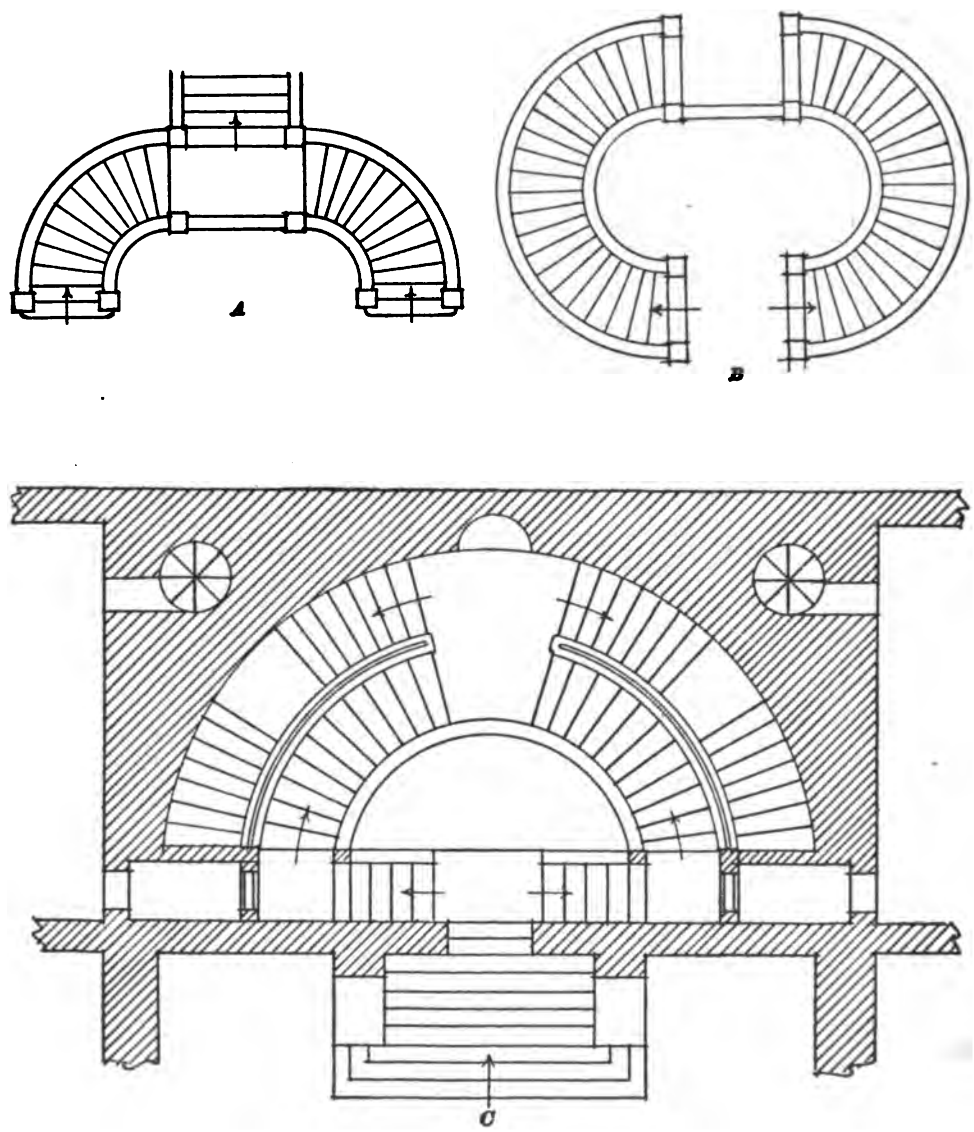


Fig. 94

upper runs; at *B*, there are three lower runs and one upper one; at *C* and *D*, there are two lower runs and two upper ones, differently disposed. The squares in the corners may in each case be on a level with either the lower, the upper, or the intermediate landing, as may be considered desirable. There is a Cruciform stairway of the fourth type under the dome of the State House at Providence, R. I.

Circular steps of 90 or 180 degrees, or even less (see Fig. 95 *A* and *B*), are often put symmetrically face to face, it being awkward to put them back to back. In the Museum at Naples is a circular symmetrical staircase (Fig. 95 *C*) which is like Fig. 90 *E*, but built on a curved axis.

Staircases.—Indoors, in the case of a single flight, ascending from one story to the next, the same dispositions are employed as outdoors, the staircase hall being open above, and covered by a ceiling—either flat, vaulted, or domed. If there is a third story, it is better, where it can be done, not to put the second stairway



STAIRCASE
NAPLES MUSEUM ·

FIG. 95

over the first, but elsewhere, nearby, as in the Paris Opera House, Fig. 84. But, as every staircase occupies floor space in two stories, this uses up a great deal of room, and it is more common to put one flight over another. In this case, a symmetrical staircase involves the use of a bridge, either horizontal, as part of the landing, or inclined, forming a run of the upper flight. Both are undesirable, and it is better to build an unsymmetrical staircase, and to attach it to the walls at every run (see Fig. 96).

The inner end of the steps, in the lower flight, from the ground floor to the next above, can, as in the figure, always be supported by a wall resting upon the ground, but going no higher than the steps, and supporting the rail, or sloping parapet. The upper flights can then either be supported on columns resting on the posts of the parapet below, with or without arches, or they may rest at one end on the wall, the other end of the steps being unsupported, like a geometrical staircase.

Sometimes there is a wall on both sides, especially when one flight is directly over the one below. In this case, the lower flight is sometimes covered only by the steps of the upper runs, which either rest their ends upon the walls or are supported by intermediate strings.

The lower runs are often covered, and the runs above them supported, by an inclined barrel vault.

Plate XVIII shows three ways in which a staircase of one run may be thus vaulted. As the second story is as high as the first, the rise of the vault is the same, as that of the stairs it covers; but as the run of the vault is shorter by the thickness of the arches at top and bottom, than that of the stairs under it, the line at the spring of the vault is steeper and the wall surface is trapezoidal. Since the third story is not as high as the second, the surface between them shows a parallelogram.

The staircases that occupy the least space are those of two runs, side by side, as shown in Fig. 97, *A* and *B*, for the landings are at a minimum. Such staircases are easy to go down, but they are fatiguing to go up, as they afford no breathing places. Moreover, they give access to only one point on each floor, and to reach other points galleries are required, as shown by the dotted lines. But if this floor space is needed for passage, it had better also be used for landings, as shown in Fig. 97 *C*. Such galleries add greatly to the appearance of the interior, especially if supported by columns (Plate XIX).

The place of the parapet, either outdoors or indoors, whether horizontal or inclined, is often taken by some form of fence as in Fig. 98, or by a balustrade, the balusters resting either on the steps or upon the string, as in Plate XVII.

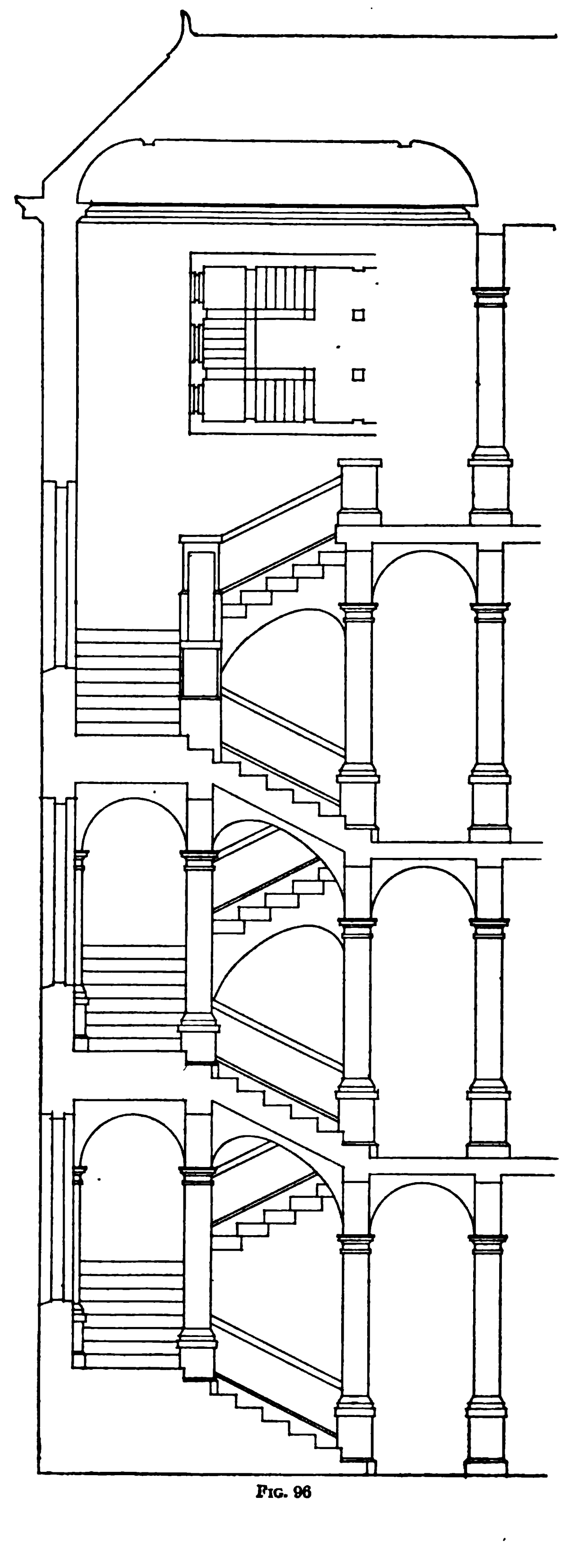


Fig. 96

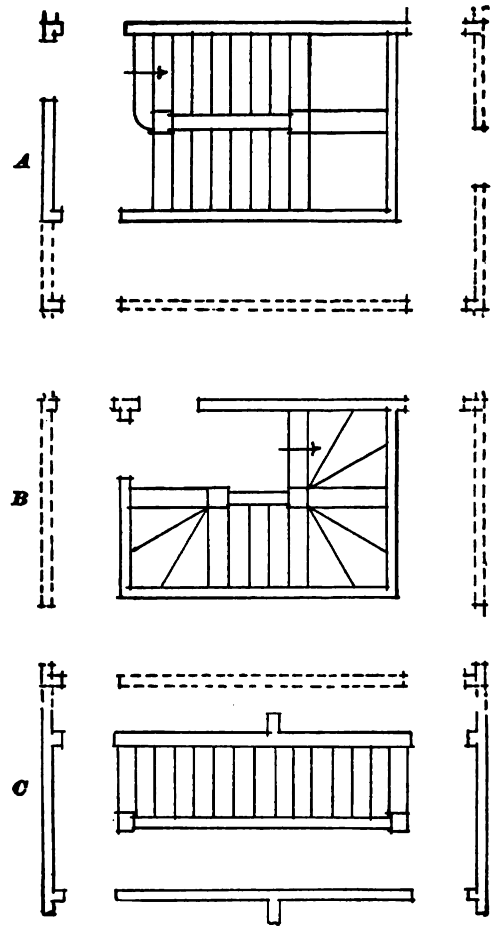


Fig. 97

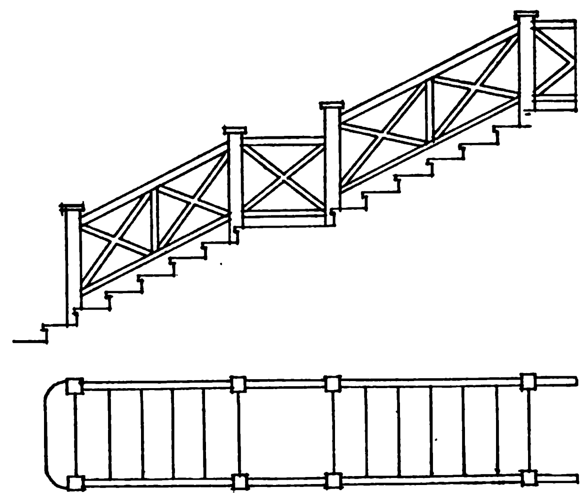


Fig. 98

Fig. 99 *A*

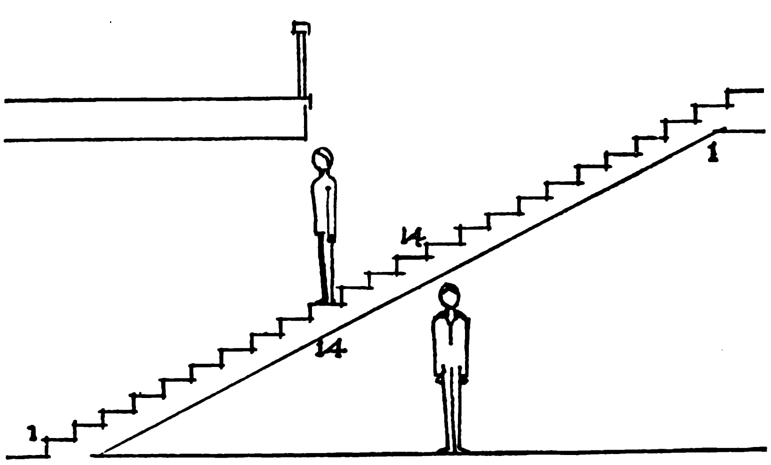


Fig. 100

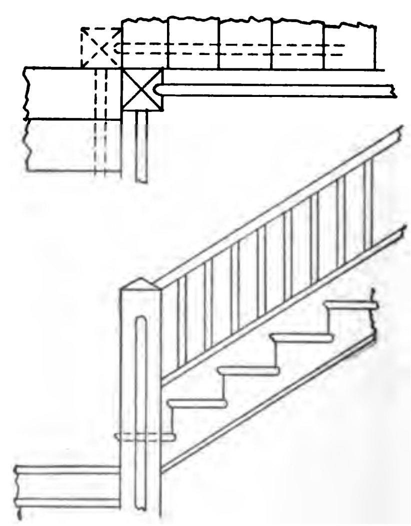


Fig. 99 *B*

Overhanging Balustrades.—When this fence is made of wood or iron, it is sometimes set entirely outside the string, and is supported either by brackets, as in Fig. 99 *A*, or merely by the posts at each end, as in Fig. 98. This virtually widens the stairway.

If the balustrade is of wood the posts which carry the *strings* that support the risers and treads are cut off, and the rail or balustrade has posts of its own, set outside the others, as is shown in Fig. 99 *B*.

Staircases built in this way, not only gain several inches in width, but are cheaper to construct, the labor of fitting the balusters into the treads being saved. They are also easier to sweep and dust.

Headroom.—It is generally possible to pass under a staircase at about the fourteenth step from the bottom, and to pass over one at the fourteenth step from the top (see Fig. 100).

Lighting.—A staircase of one flight, under a high ceiling, vault, or dome, may conveniently be placed in the center of a building and lighted from the top. But if there are several flights, one over another, very little light will penetrate below the upper stories, and it is better to place the staircase against an outer wall. The windows in this wall serve, then, as a sort of vertical lantern, illuminating the whole interior, and do double service, since those on each landing light two stories, and each story is lighted both from above and from below (see Fig. 96).

Circular and Spiral Staircases, consisting entirely of winders, are sometimes built around a circular post or newel (Fig. 101). When built of stone, the riser, or face of each step, lies generally on a radius of the circle, as shown at *A*. But the back of the step is, for strength, made tangent to the newel-post, as at *B*, and the under side is generally cut away so as to give more headroom. Such staircases are generally only a few feet wide. Greater width makes too much difference between the width of the treads at the outer and inner ends of the steps, as is to be seen in the great staircase at Blois.

At the house known as Cooke's Folly, at Clifton, in England, are two spiral staircases one within the other, the inner one for servants (Fig. 102).

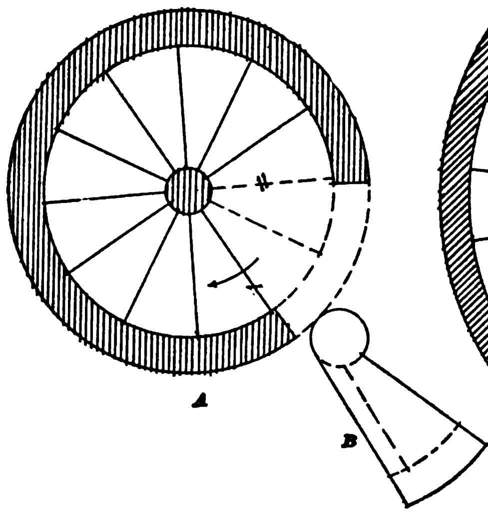


Fig. 101

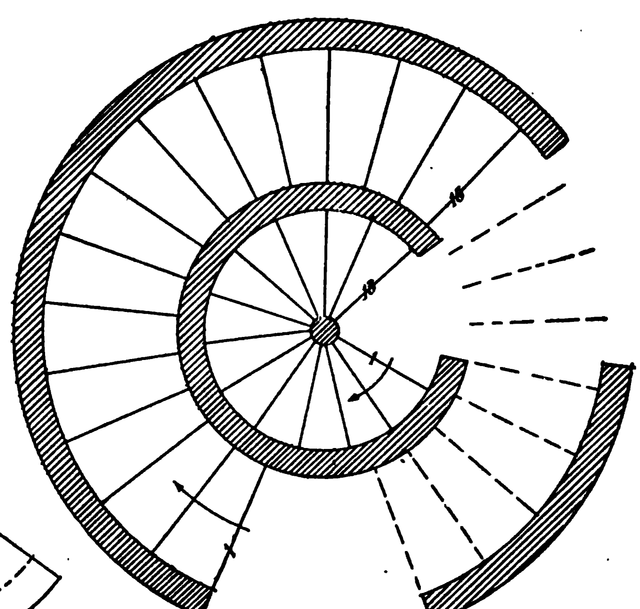
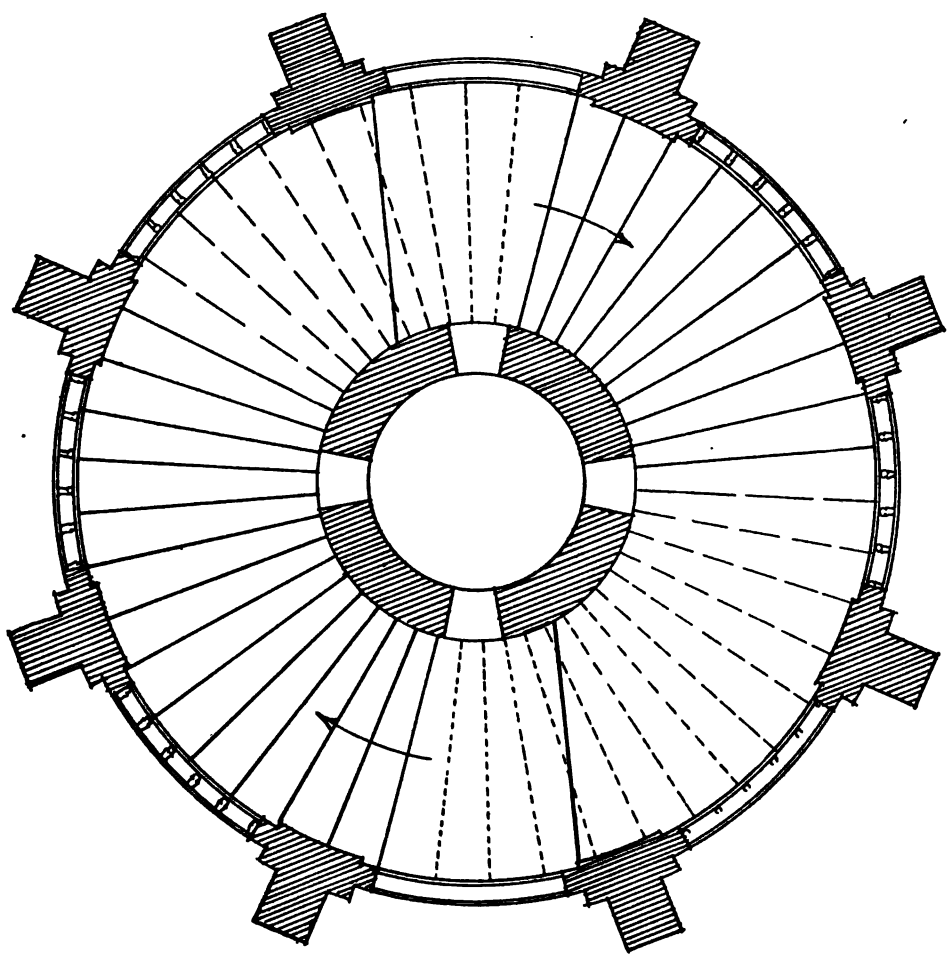


Fig. 102

Spiral staircases are generally built around a well, which is commonly enclosed with a wall to support the inner ends of the steps. But there is a circular staircase in the Palace of Caprarola, and elliptical ones in the Vatican and in the Barberini Palace, in which the inner wall is replaced by columns.

At Orvieto is a well, built by San Gallo, 200 feet deep, around which are two spiral staircases of easy grade, one above the other, so that donkeys descend on one side with buckets to be filled, and ascend on the other. There was formerly a similar double staircase in the Louvre, built by Charles V, and there is one at the Chateau de Chambord, built by Francis I, ascending from the ground floor to the roof of the castle (see Fig. 103). Rectangular stairways have been built upon the same principle.



· STAIRCASE ·
· CHAMBORD ·
FIG. 103